The Engineer

MARCH 27, 1953 28, ESSEX ST., STRAND, LONDON, W.C.2 TWO SHILLINGS

UNIVERSITY OF MICHIGAN
APR 9 1953
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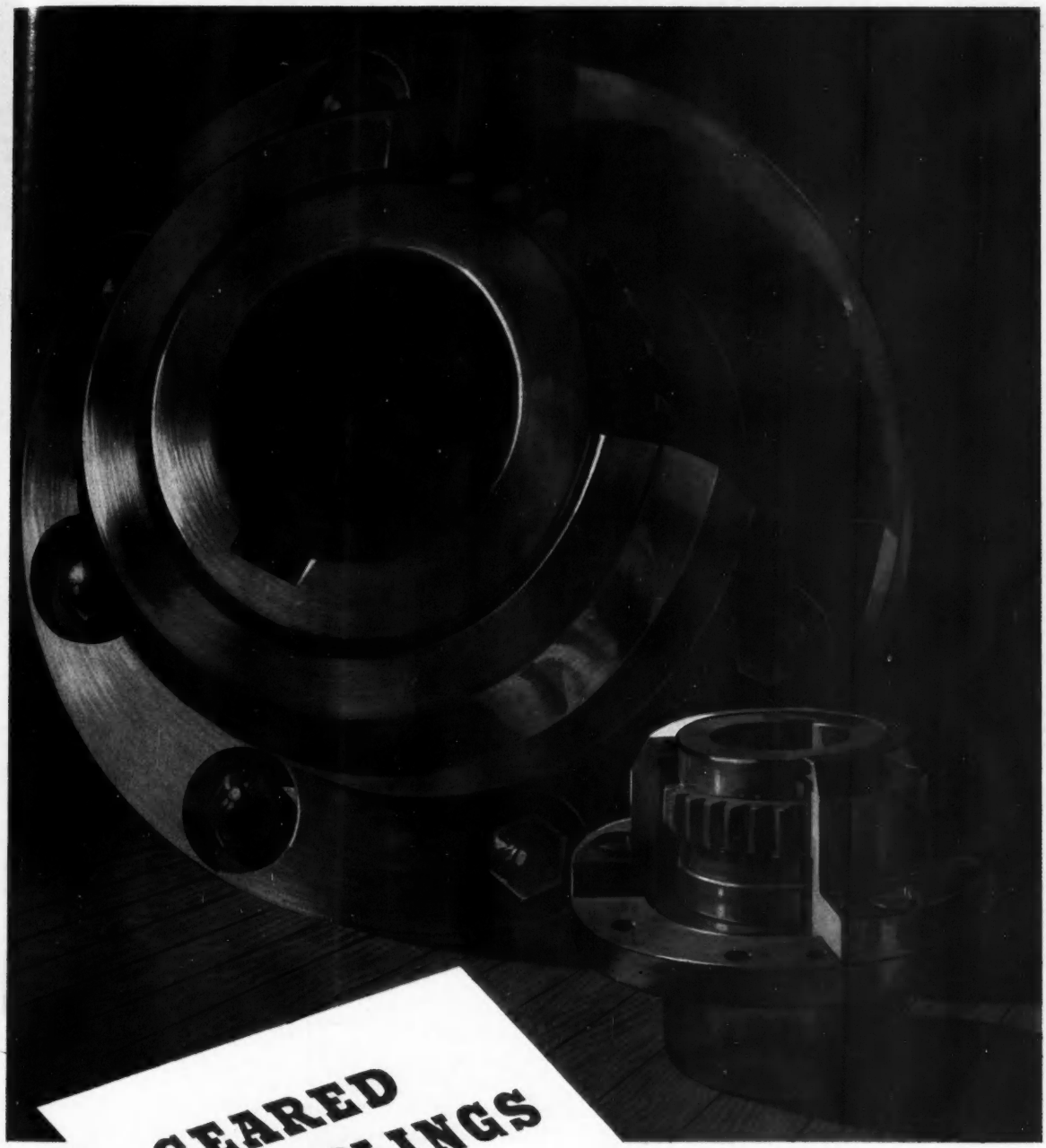

Moss Gear geared couplings are designed to compensate for shaft misalignment caused by changes of temperature, subsidence of foundations or vibration, and to allow the free lateral float of connected shafts.

The shock of sudden reversal is adequately borne by these geared couplings without damage to themselves or to the machines they connect.

THE MOSS GEAR CO LTD

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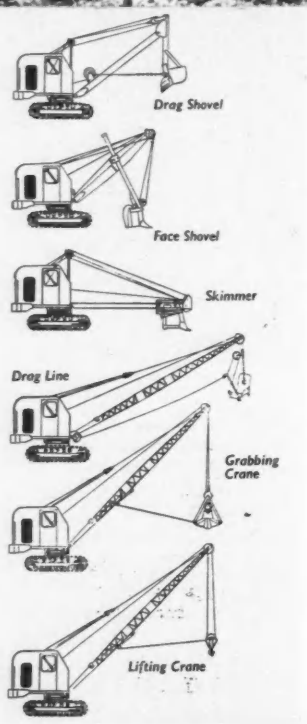
'BK Fifty'

½ cu. yd. EXCAVATOR

"BK-Fifty" Dragline with 40-foot boom

The Face Shovel embodies a Positive Power Crowd which ensures a full bucket every swing.

*360° Circle of Swing



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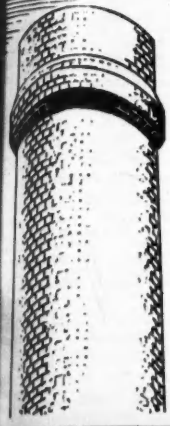

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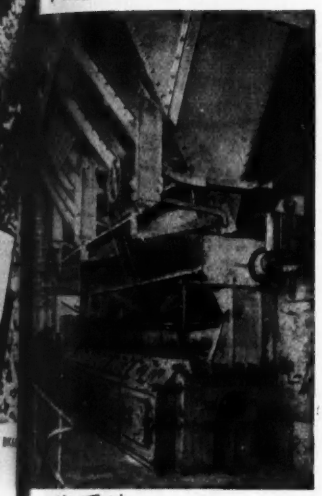

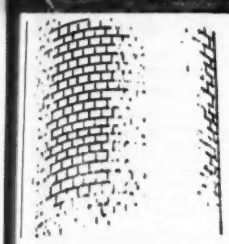

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BOILERS

ARKE, CHAPMAN specialise in the design and manufacture of all kinds of elded pressure vessels for the petroleum, chemical and other industries. Our rkshops are equipped with new plant for the efficient fabrication, heat atment and rigorous radiographic examination of fusion welded vessels the requirements of the principal surveying authorities in this country.

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PRINCIPAL CONTENTS

(Complete contents on page 462)

The Productivity Conference... 462

Water Power in the Italian Alps—No. VII ... 446

The Training of Radiologists for Industry ... 448
(J. C. ROCKLEY)

Admiralty Test House for Gas Turbines 452

B.S.R.A. Resistance Experiments on the "Lucy Ashton"—No. I... 467
(J. F. C. CONN, H. LACKENBY and W. P. WALKER)

Automatic Control of Open-Hearth Furnaces ... 456

Silicone Resins in Insulation at Power Frequencies 471
(W. J. RENWICK and J. R. REED)

Naval Gas Turbines 463

NOTICE TO READERS

All letters intended for insertion in 'The Engineer' or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

SUBSCRIPTIONS

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WORDING OF ADVERTISEMENTS: Approximately the first 25 letters of each advertisement are set in heavy type. Advertisers are therefore advised to begin their advertisements with the words they want emphasized.

Advertisements received by Mid-day Tuesday will appear in the issue of Friday the same week. Orders must be accompanied by a remittance.

INDEX TO ADVERTISERS—PAGE 135

PUBLIC APPOINTMENTS

UNIVERSITY OF GLASGOW

DEPARTMENT OF MECHANICAL ENGINEERING

LECTURESHIP

Applications are invited for a LECTURESHIP IN MECHANICAL ENGINEERING, with special reference to applied thermodynamics, tenable from 1st October, 1953, or such earlier date as may be arranged. The salary scale for the grading in question is £500 by £50 to £1100, but for a candidate with the experience and qualifications in view the commencing salary would be about £800.

There will be ample opportunity for the Lecturer to pursue research work.

F.S.S.U. and family allowance benefits.

Applications (six copies), including the names of three referees, should be lodged not later than 15th May, 1953, with the undersigned, from whom further particulars may be obtained.

ROBT. T. HUTCHESON,
Secretary of University Court.
E7763

UNIVERSITY OF MELBOURNE

AUSTRALIA

SENIOR LECTURER IN HYDRAULIC ENGINEERING

Applications are invited for a position of SENIOR LECTURER IN HYDRAULIC ENGINEERING.

Salary : £A1234 to £A1484 per annum (including £A234 cost of living allowance), commencing salary according to qualifications. Superannuation is similar to F.S.S.U.

Duties : Teaching, research and other work in Hydraulic Engineering, including design work for new laboratory.

Further particulars and information as to the method of application should be obtained from the Secretary, Association of Universities of the British Commonwealth, 5, Gordon Square, London, W.C.1.

The closing date for the receipt of applications in London and Australia is 18th May, 1953. E7882

UNIVERSITY OF SYDNEY

AUSTRALIA

LECTURER IN MECHANICAL ENGINEERING

Applications are invited for the position of LECTURER IN MECHANICAL ENGINEERING. Special experience in Heat Engines and/or Fluid Mechanics will be an advantage.

The salary will be within the range of £A650–£A1000 per annum, plus cost of living adjustment (at present £A239 males and £A182 females), with annual increments of £A50. The salary is subject to deductions under the State Superannuation Act. The commencing salary will be fixed according to the qualifications and experience of the successful candidate.

Further particulars and information as to the method of application should be forwarded to the Secretary, Association of Universities of the British Commonwealth, 5, Gordon Square, London, W.C.1.

The closing date for the receipt of applications, in London and Australia, is 30th April, 1953. E7883

UNIVERSITY OF GLASGOW

FACULTY OF ENGINEERING

ADMISSIONS—SESSION 1953–54

Students who intend to enter the FACULTY OF ENGINEERING for the first time in October, 1953, must obtain a form of application for admission from the undersigned, which should be returned not later than 30th May, 1953.

ROBT. T. HUTCHESON,
Registrar.
E7958

THE UNIVERSITY OF MANCHESTER

LECTURER IN ENGINEERING

Applications are invited for the post of LECTURER IN ENGINEERING. Candidates should have qualifications in Civil Engineering, with special interests in Structures or Hydraulics. Salary scale, £500–£1100 per annum, with membership of F.S.S.U. and Children's Allowance Scheme. Initial salary according to qualifications and experience. Applications should be sent not later than 25th April, 1953, to the Registrar, the University, Manchester, 13, from whom further particulars and forms of application may be obtained. E7954

THE NORTH OF SCOTLAND COLLEGE OF AGRICULTURE

ASSISTANT LECTURER IN AGRICULTURAL ENGINEERING

Applicants for this post should possess a Degree in Engineering and/or in Agriculture, with practical experience of Farm Implements and Machinery. Salary scale according to age and qualifications on scales ranging from (Men) £360 to £835 per annum, plus pay addition in each case. Superannuation scheme. Applicants must be prepared to serve in any part of college area. Application forms obtainable from Secretary of College to be lodged not later than 11th April, 1953.

41½, Union Street,
Aberdeen. E7866

PUBLIC APPOINTMENTS

THE UNIVERSITY OF LEEDS

DEPARTMENT OF MECHANICAL ENGINEERING

ASSISTANT LECTURER OR LECTURER IN MECHANICAL ENGINEERING

The Council invites applications for a post of ASSISTANT LECTURER or LECTURER in MECHANICAL ENGINEERING ; salary on the scale £500 by £25 to £550 for an Assistant Lecturer or £550 by £50 to £1100 for a Lecturer, according to qualifications and experience. Candidates should have an Honours Degree and some practical experience.—Applications (three copies), stating age, qualifications and experience, together with the names of three referees, should reach the Registrar, The University, Leeds, 2 (from whom further particulars may be obtained), not later than 27th April, 1953. E7910

GLAMORGAN EDUCATION COMMITTEE

GLAMORGAN TECHNICAL COLLEGE

LECTURER IN MECHANICAL ENGINEERING

Required for September, 1953, at the Glamorgan Technical College, Treforest, LECTURER IN MECHANICAL ENGINEERING, able to teach Theory of Machines and Machine Design, plus one other subject to Degree and Diploma standard. Candidates must possess a University Degree in Mechanical Engineering or an equivalent professional qualification. Teaching experience is essential and industrial or research experience desirable. Salary in accordance with the Burnham Technical Award, viz., £900 by £25 to £1000, plus £40 special addition to salary. Application forms, obtainable from the undersigned on receipt of a stamped, addressed, foolscap envelope, must be returned by 4th April, 1953. Canvassing will disqualify.

EMLYN STEPHENS,
Director of Education.
County Hall,
Cardiff. E7871

CIVIL SERVICE COMMISSION

ROYAL MILITARY ACADEMY, SANDHURST

LECTURERS AND SENIOR LECTURERS

The Civil Service Commissioners invite applications from men for the following posts under the War Department :—

TWO SENIOR LECTURERS : one Mathematics (short service), one Science (long service) ; SIX LECTURERS (short service), two Mathematics, three Science, one Modern Language. There may be additional posts. Candidates must have (or obtain in summer, 1953) an appropriate degree (at least a Second Class Honours) or equivalent.

Age at least 21 years on 1st August, 1953.

Candidates selected for short-service posts will be considered for permanent posts when they become available.

Inclusive salary scales :—Senior Lecturer, £864 to £1126 ; Lecturer, £417 to £760. Starting salaries above minimum in approved cases. The Superannuation Acts apply to long-service posts.

Successful candidates expected to take up duty by September, 1953.

Further particulars and application forms from Secretary, Civil Service Commission, Burlington Gardens, London, W.1, quoting No. 4196/53. Application forms must be returned by 9th April, 1953. E7920

SOUTH-EAST ESSEX TECHNICAL COLLEGE AND SCHOOL OF ART

LONGBRIDGE ROAD, DAGENHAM

Principal : F. HEATHCOAT, M.Sc., Ph.D., F.R.I.C., F.I.M.

HEAD OF ENGINEERING DEPARTMENT

Applications invited for post of HEAD OF ENGINEERING DEPARTMENT (Burnham Report Grade III).

Salary : £1190 by £25 to £1340 (man), plus £36 or £48 London Allowance.

Applicants should possess a good Engineering Degree and have had suitable industrial, teaching and administrative experience. Further particulars and application form obtainable from the Chief Education Officer, County Offices, Chelmsford (stamped, addressed foolscap envelope), and returnable by 7th April. E7848

SOUTH-EAST ESSEX TECHNICAL COLLEGE

LONGBRIDGE ROAD, DAGENHAM

ASSISTANT (GRADE "B") IN ELECTRICAL ENGINEERING

Required, in September, an ASSISTANT (GRADE "B") in ELECTRICAL ENGINEERING. Candidates should have a Degree or equivalent qualification and some industrial experience, and will be required to teach to Higher National Certificate standard.

Salary : £490 by £25 to £765, plus London allowance (£36–£58). Increments for approved industrial and teaching experience and war service ; additions for training and graduate qualifications.—Further particulars obtainable from the Clerk to the Governors at the College (stamped, addressed, foolscap envelope). E7968

PUBLIC APPOINTMENTS

ADMIRALTY

ROYAL NAVAL SCIENTIFIC SERVICE

ENGINEERS AND PHYSICISTS

ENGINEERS and PHYSICISTS (particularly with Electronics) required for appointments in (a) Senior Scientific Officer and Scientific Officer grades (Ref. A246/52A), and (b) Experimental Officer and Assistant Experimental Officer grades (Ref. A247/52A) in Experimental Establishments in London, Portsmouth, Weymouth areas and Scotland. Candidates, British subjects, for (a) must possess First or Second-Class Honours Degree in Physics or Engineering, or high professional attainments such as Corporate Membership of appropriate professional institution with suitable experience and responsibility, and for (b) should possess one of following qualifications :—University Degree in Science, Engineering or Mathematics ; Graduate Membership of appropriate professional Institution ; Higher National Certificate ; Final Certificate of five-year grouped course in relevant subject at City and Guilds of London Institute, or comparable Institution ; Higher School Certificate with Mathematics or Science as principal subject, or equivalent qualification. S.S.O.s at least 26 years of age with at least three years' approved experience, London salary (men), £812–£1022 per annum ; S.O.s at least 21 years, £440–£707 ; E.O.s at least 26 years, £628–£786 ; A.E.O.s at least 17½ years, £274–£586. Rates for women and posts in Provinces somewhat lower. Starting salaries above minima may be granted according to age and experience. All appointments unestablished (with F.S.S.U. for S.S.O. and S.O.), but with some opportunities to compete for established posts.—Application forms, from M.L.N.S., Technical and Scientific Register (K), Almack House, 26, King Street, London, S.W.1, quoting appropriate reference. E7966

CITY OF BIRMINGHAM

PUBLIC WORKS DEPARTMENT

ENGINEER-IN-CHARGE

Applications are invited for the post of ENGINEER-IN-CHARGE of the Mechanical and Lighting Section.

Candidates should be Corporate Members of both the Institution of Mechanical and the Institution of Electrical Engineers. They should be good administrators and have had considerable experience in :—

Mechanical and Automobile Engineering.
Electrical Engineering.
Heating and Ventilating Engineering.
Street Lighting, &c.

Experience with a large local authority will be an advantage.

Salary, £1500/£50/£1750 per annum, in accordance with the qualifications and experience.

The post is permanent, superannuable and subject to a medical examination.

Applications endorsed "Mechanical and Lighting Engineer," stating age, qualifications and experience, together with the names and addresses of two persons to whom reference can be made, should reach the undersigned not later than the 25th April, 1953.

Canvassing disqualifies.

H. J. MANZONI,
City Engineer and Surveyor.
Civic Centre,
Birmingham, 1. E7948

MINISTRY OF SUPPLY

ENGINEER

Ministry of Supply require ENGINEER at Risley, near Warrington, for organisation and technical administration of branch responsible for inspection of plant and equipment. Considerable travelling involved. Qualifications : British of British parentage ; recognised engineering apprenticeship ; Corp. Mem. of Inst. of Civil, Mech. or Elec. Engineers or exempting qualifications. Executive experience essential in heavy or medium electrical industry or similar mech. experience with blowers, pumps, &c. Salary : within £1256–£1454. Appointment unestablished, but opportunities may arise for established pensionable posts.—Application forms from M.L.N.S. Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1, quoting D312/52A. Closing date 17th April, 1953. E7919

SOUTH-WEST METROPOLITAN REGIONAL HOSPITAL BOARD

ENGINEERING DRAUGHTSMAN

Applications are invited for the appointment of ENGINEERING DRAUGHTSMAN on the Board's headquarters staff. Salary scale :

£360 p.a. at age 21 or over by £20 (4) by £25 (1), £20 (4) to £545 p.a., plus London weighting of £20–£30 according to age.

Applicants should be neat and accurate draughtsmen, with experience of the layout and design of heating, hot water, ventilating and electrical services of large buildings, and must have had suitable training, including three years' technical experience in engineering drawing, and also have had site or workshop experience.

Applications, stating age, qualifications, experience and present appointment, and giving the names and addresses of two referees, should be sent to the undersigned not later than 7th April, 1953.

E. G. BRAITHWAITE,
Secretary.
South-West Metropolitan Regional Hospital Board,
11A, Portland Place,
London, W.1. E7969

PUBLIC APPOINTMENTS

CROWN AGENTS FOR THE COLONIES

LONDON OFFICE

ASSISTANT ENGINEER (MECHANICAL)

ASSISTANT ENGINEER (MECHA... required for the London Office. Salary scale £25 to £750 by £30 to £900 a year. ... minimum is linked to entry at age 25 and ... to increase at the rate of one increment for ... above that age up to, but not exceeding ... Fully qualified officers of at least 27 years of ... have completed at least two years' satisfactor... are eligible, under certain conditions, for ... increase in salary of £75. Pay addition to be ... payable at the rate of 10 per cent on first £... 5 per cent on second £500. Extra duty allo... 8 per cent on basic annual salary plus pay ... also payable at present. Engagement ... unestablished terms with a prospect, after ... service, of appointment to the established ... sionable staff in due course, vacancies permi...

Qualifications : Candidates between 2... years of age should have passed the ... examination for Associate Membership ... Institution of Mechanical Engineers, or ... examination. They should have served ... ticeship or pupilage in the Locomotive or ... Stock Department of the British Railways, ... firm of locomotive or rolling stock builders, ... firm specialising in the manufacture of ... breakdown cranes. They should also have ... drawing-office experience in the design of ... or carriages and wagons and diesel railcars ... together with a sound knowledge of modern ... practice. Duties include preparation of ... specifications, examining and approving ... design calculations and technical correspon...

Apply at once by letter, stating age, full ... block letters, and full particulars of qualifica... experience, and mentioning this paper, to the ... Agents for the Colonies, 4, Millbank, ... S.W.1, quoting on letter M.29209.B. The ... Agents cannot undertake to acknowledge all ... tions, and will communicate only with ... selected for further consideration.

THE METROPOLITAN WATER BOARD

APPOINTMENT OF ASSISTANT ENGINEER (MECHANICAL)

Applications are invited for appointment ... ASSISTANT ENGINEER (MECHANICAL) ... the permanent pensionable staff. Salary ... £719–£886 per annum. Commencing salary ... ing to age, qualifications and experience. Ma... age 45 years. It is a condition of the appointm... and the continued holding of this position ... selected candidate shall be and continue a ... subscribing member of the Institution of Mech... Engineers.

Responsible experience in the layout, specifi... design and installation of all types of water p... plant is necessary.

Housing accommodation may be available.

Particulars and a form of application ... obtained from the undersigned on receipt ... stamped addressed foolscap envelope ... reference (A).

W. S. CHEVALIER,
Clerk of the Boa...
Offices of the Board, New River Head, Ros... Avenue, London, E.C.1. E...

TRENT RIVER BOARD

APPOINTMENT OF TWO ENGINEER ASSISTANTS

Applications are invited for the appointme... TWO ENGINEERING ASSISTANTS, one ... Board's Head Office, Nottingham, and the ot... the Board's Divisional Office at Gainsborough.

The salaries will be within A.P.T. Grades I to ... (£465–£685 per annum) of the National Sche... Conditions of Service, according to experience ... qualifications.

Preference will be given to candidates who ... had experience in land drainage works. Suc... candidates will be employed on the design ... execution of extensive river improvement wo...

Applications, with full particulars, including ... of testimonials or the names of referees, must ... the Engineer to the Board, Trent River Board, ... Derby Road, Nottingham, within fourteen da... the date of the publication of this advertisement.

JOHN HIRST,
Clerk of the Boa...
E7930

MINISTRY OF SUPPLY

SPECIALIST TECHNICAL EDITO...

Ministry of Supply require SPECIALIST TE... NICAL EDITOR at Chessington, Surrey, to pr... instructional textbooks on guided weapons, inv... collation of information and editing contribu... Qualifications : British of British parent... Honours Degree in Maths., Physics or Engine... and ability to deal with maths. up to at least D... standard. Experience of (i) teaching or writing ... editing technical textbooks desirable, (ii) engine... research and development advantageous. Sal... within £822–£927. Appointment unestablished ... opportunities may arise for established pensio... posts.—Application forms from M.L.N.S., Tech... and Scientific Register (K), Almack House, 26, ... Street, London, S.W.1, quoting A76/53/A. C... date 25th April, 1953. E7...

THE ENGINEER

MARCH 27, 1953

The Factory Equipment Exhibition

THE first Factory Equipment Exhibition was opened in London at the New Horticultural Hall on Monday last, March 23rd, by Sir Miles Thomas. This exhibition, which closes to-morrow, Saturday, March 28th, has been organised to stimulate the interest of industrial executives, welfare and personnel officers, and others concerned with the control of factories, in modern equipment for administration, safety and welfare. The products of nearly a hundred manufacturers are exhibited, and they include costing and accounting systems, office furniture, communication equipment, dust-removal equipment, handling plant, safety clothing, welfare equipment, canteen plant, &c. As all managements are aware, it is not always easy to get employees, particularly women, to make full use of the protective clothing which is available, and in order to show that such clothing can be attractive as well as effective a special mannequin parade is being held at regular intervals during the course of the exhibition. In these parades, typical protective clothing for steel plant workers, miners, workers in industries handling dangerous acids and other liquids is shown, as well as various designs of overalls, boiler suits, headwear, &c. Many kinds of goggles, face shields and breathing masks being demonstrated in these parades are designed to give full protection, whilst, at the same time, enabling the user to work with freedom and unobstructed vision.

Steel Founders' Convention

THE British Steel Founders' Association has announced this week some particulars of a "customer-founder" convention which it proposes to hold at 45, Park Lane, London, W.1, on Wednesday, Thursday and Friday, April 15th, 16th and 17th. The convention is to be opened at noon on April 15th by the Minister of Works, Mr. David Eccles. During the three days there are to be four sessions, at which papers, prepared both by makers and users of steel castings, will be read and discussed. At the same time, two exhibitions are being arranged. One of them will be devoted to the metallurgy of steel castings and to their design, while the other is to be a display representative of the many uses to which steel castings are put by the different branches of the engineering industry. It is stated that actual castings from a few ounces up to 5 cwt in weight will be included in the exhibitions, together with models of others up to 150 tons. The object of this convention, which it is believed is the first of its kind to be held, is to bring together designers, makers and users of steel castings so that they may have an opportunity of hearing each other's problems and difficulties and of formulating plans to ensure closer co-operation and greater mutual satisfaction in the future. The convention and its accompanying exhibitions will not be open to the general public.

Duty-Free Machinery Imports

AT the end of last week, the President of the Board of Trade, Mr. Peter Thorneycroft, stated, in a written Parliamentary answer, that, after consultation with the Chancellor of the Exchequer, he had decided to set up an independent committee to review the long-term production of the duty-free entry of machinery. The terms of reference of the committee are: "To consider and report whether it is in the national interest to provide for the duty-free admission into the United Kingdom of machinery, either by classes or in individual consignments, and, in this connection, to review the provisions of Section 10 of the Finance Act, 1932, and their administration, and to recommend what, if any, changes should be made." Sir Henry Wilson Smith, a director of Powell Duffryn, Ltd., has agreed to serve as chairman of the committee, the other members of which are: Mr. Roland Bird, assistant editor of *The Economist*; Mr. T. F. H. Board, chairman of John Watney and Co., Ltd.; Mr. M. A. Fiennes, M.I.Mech.E., managing director of Davy and United Engineering Company, Ltd.; Mr. C. H. Grist, joint managing director of Blaw Knox, Ltd.; Mr. E. Grove, director of James Grove and Sons, Ltd.; Mr. S. J. Harley, M.I.Mech.E., chairman of the Coventry Gauge and Tool Company, Ltd.; Mr. A. V. Symons, chairman of Tootal, Broadhurst, Lee Company, Ltd., and Mr. Jack Tanner, president of the Amalgamated Engineering Union. This announcement by the President of the Board of Trade follows the statement made by the Chancellor of the Exchequer, in his Budget speech last year, that the issue of licences for the duty-free import of machinery would be suspended for the time being, but that the long-term problem involved would be examined in consultation with industry.

Steel Castings Research

THE British Steel Castings Research Association has now been formed to take over the work which has hitherto been done by the research and development division of the British Steel Founders' Association. Mr. F. N. Lloyd is the first chairman of the council of the new association, and Mr. J. F. B. Jackson has now become director of the association. Mr. Jackson, as director of research to the British Steel Founders' Association, has been responsible for the research and development work which was started in 1949. The British Steel Castings Research Association's programme is being sponsored by various universities, and is also conducted by its permanent staff in its own research stations, and in conjunction with the research departments of industrial concerns. Researches in recent years have been devoted to many aspects of steel casting science and foundry technology and have included a series of projects related to industrial health and foundry dust suppression. The association's dust research station in Sheffield has been in operation since the middle of 1951. Important advances have also been made with work on the non-destructive testing of steel castings. Another item of research work is that concerned with the freezing of steel in refractory moulds, which is being conducted at Durham University and the Imperial College of Science. At Cambridge University research has been proceeding, during the last three years, on the metal penetration problem and on the improvement of surface finish in steel castings. Ever since the research and development division of the British Steel Founders' Association was started in 1949, the problem of translating the results of its work in practice has been fully recognised. The British Steel Castings Research Association intends to continue these efforts, which are aimed at bringing science into practice.

The Annual Report of the D.S.I.R.

THE thirty-seventh annual report of the Department of Scientific and Industrial Research has been published this week. In a preface to the summary of the work in hand by the research organisations included in the D.S.I.R., the chairman of the Advisory Council, Professor Sir Ian Heilbron, F.R.S., has referred to the anxiety, expressed in the last report, caused by the delay in advancing D.S.I.R.'s post-war plans. In the last report it was urged that the economic obstacles hindering the proper expansion of its work should be removed, but Sir Ian maintains that it is still necessary to review the relation between our scientific needs and our scientific resources with steadily deepening concern. The report says that the total number of staff of all grades employed in the Department on October 1, 1952, was 4035, and the net expenditure in the year ended March 31st amounted to £4,956,819. Over 200 pages of the report are devoted to reviews which summarise the work carried out by the various research organisations of the D.S.I.R. The report emphasises the growing interest the Department takes in operational research. Mention is made of the pioneer work of the Cotton and the Boot and Shoe Research Associations in this field and its more recent application by the wool industry and other research associations. Amongst some surveys there has been one into the optimum size of ships which can be handled in docks, and in connection with this work unloading methods have been investigated to determine the reasons for the rapid ship discharges characteristic at certain foreign ports. The human problems in industry, the report notes, form another subject, the importance of which is gaining increasing recognition, and two committees have now been formed to review the needs of this work. One committee is to be responsible for efficiency investigations concerning itself with work measurement and methods of work, the effects of work environment and of particular tasks upon the individual. The other committee will be concerned with the development of human relations in industry.

A Flood Investigation Committee

ON Monday last, March 23rd, there was a debate in the House of Commons on the motion, which was eventually agreed to, "that this House accepts the principle enunciated by the Prime Minister that the damage inflicted on various parts of the United Kingdom by flood and tempest on January 31 and February 1, 1953, requires to be treated on a national basis, and owing to the magnitude of the catastrophe expects that principle to be fully implemented by Her Majesty's Government." Most of the debate was concerned with questions relating to compensation, but during its course the Home Secretary, Sir D. Maxwell Fyfe, gave details of the committee which has been formed to consider the problems of the flood disaster, including the causes of the floods, the possibilities of their recurrence, and the margin of safety for sea defences which would be reasonable and practicable. The Home Secretary pointed out that he could not yet give a full list of members of the committee as two or three names were still outstanding. As had already been announced, the chairman would be Lord Waverley (who is chairman of the Port of London Authority). Those who had accepted the Government's invitation to give their services were Sir Donald Fergusson, formerly Permanent Secretary of the Ministry of Fuel and Power, and Ministry of Agriculture and Fisheries; Sir Claude Inglis, Director, Hydraulics Research Station, Department of Scientific and Industrial Research; Mr. Leach, partner in Peat, Marwick, Mitchell and Co., formerly Deputy Financial Secretary of the Ministry of Food; Sir Basil Neven-Spence, Lord Lieutenant of Zetland; Professor J. Proudman, F.R.S., Professor of Oceanography at the University of Liverpool; Mr. Quartermaine, President of the Institution of Civil Engineers and lately Chief Engineer of the Great Western Railway; Lord de Ramsey, Lord Lieutenant of Huntingdonshire; Professor J. A. Steers, Professor of Geography in the University of Cambridge; Sir John Wrigley, lately Joint Deputy-Secretary of the Ministry of Housing and Local Government, and Mr. T. Yates, General Secretary of the National Union of Seamen.

Water Power in the Italian Alps

No. VII—(*Continued from page* 414, *March* 20*th*)

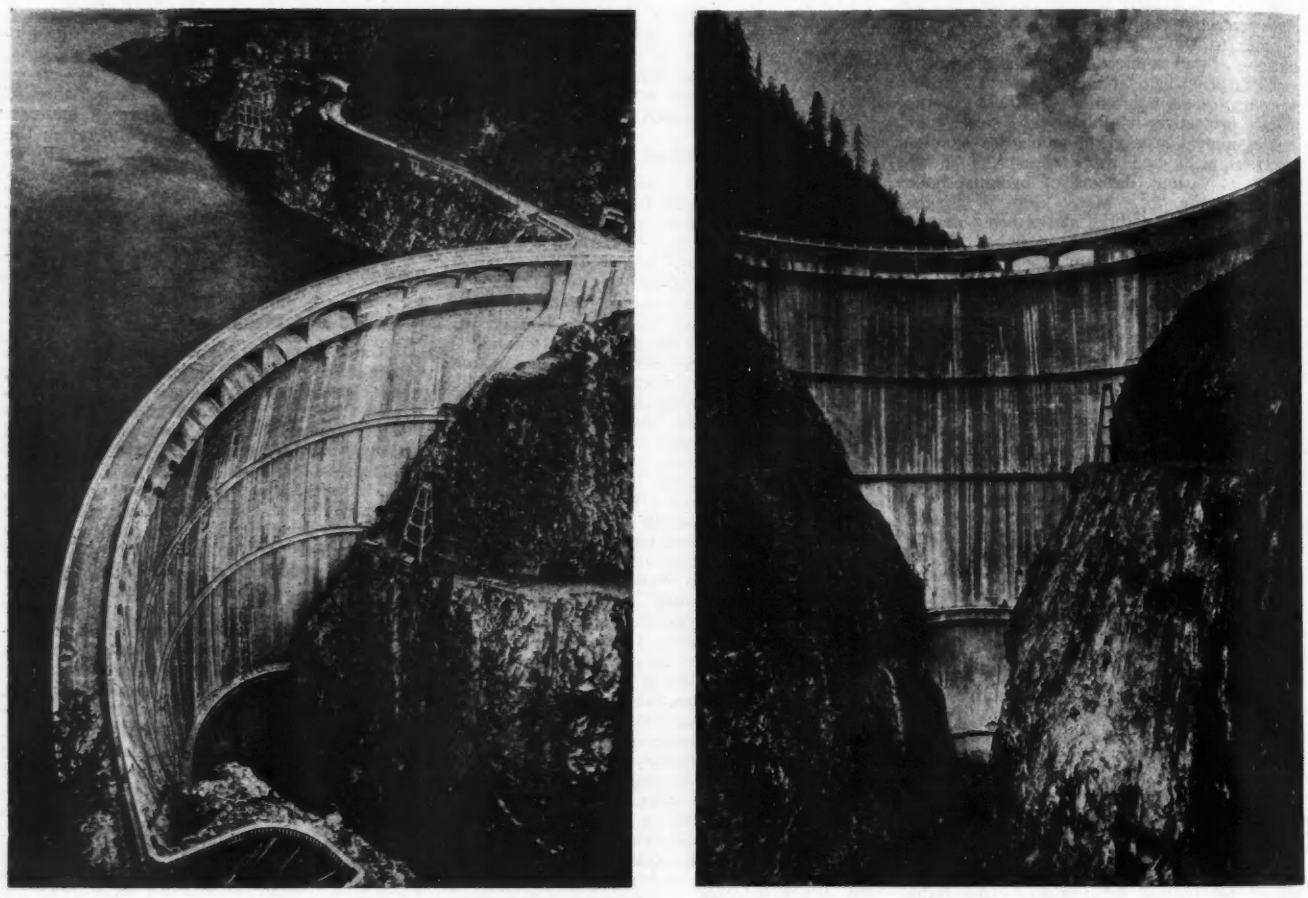
Some of the works of the Societa Adriatica di Elettricita, a public supply company which has developed a number of catchments in the Eastern Alps, are described here. Particular reference is made to the design of arch and cupola dams.

THE more recent works of the Societa Adriatica di Elettricita in the eastern region of the Italian Alps are probably better known in this country than many other of the schemes mentioned in this series of articles, largely owing to the paper presented last March at the Institution of Civil Engineers* by that company's chief engineer. A description of these works has been given here, however, as they are of exceptional interest; but more detailed information about several of the dams will be found in the paper.

The Lumiei dam is one of the highest arch dams which have been built so far (when first completed it was the highest in existence). The photographs reproduced herewith (Figs. 44 and 45) give an idea of its impressiveness. It is situated in the Carnic Alps on the Lumiei river, a tributary of the Tagliamento, (the Tagliamento flows into the Adriatic sea at a point about halfway between Venice and Trieste) and forms a seasonal storage reservoir with a capacity of 60,700 acre-feet, which is supplied by catchwater tunnels from the headwaters of neighbouring streams, as well as from the natural catchment of the Lumiei. From this reservoir a diversion tunnel about 4km in length leads to a peak load power station, from which the diverted water flows back into the Lumiei river. The power station is underground and has three 19·5MW horizontal turbo-alternator sets installed in it, each consisting of an alternator driven by two Pelton wheels. The annual power production is about 170 million kWh (100 million kWh in the winter) now that the waters of the Upper Tagliamento have been diverted into the reservoir. Extensions of the project for the utilisation of the resources both further upstream and further downstream have been designed.

The dam itself is the most interesting part of the development. It is a cupola dam with a total height of 440ft and a maximum thickness of 16m; it is shown in sectional elevation in Fig. 46. Concrete of high strength and impermeability was required for its construction, and a mix with 190kg of ferro-pozzolanic cement per cubic yard (maximum aggregate size 80mm) was employed; pozzolana, which was obtained from a quarry near Rome, was added in the manufacture of the cement in the ratio 1 : 3. The strength of the resulting concrete, from cube tests, averaged about 340kg per square centimetre at twenty-eight days. The addition of pozzolana to the normal constituents of Portland cement (a ferric clinker is prepared for grinding with the pozzolana), a practice used for a number of recent Italian dams, gives several advantages in the resulting concrete, notably: (*a*) greater impermeability, (*b*) better resistance to waters containing sulphates, of which the Lumiei river contains appreciable quantities, (*c*) lower heat of hydration of the concrete. The principal requirement in this case was a compact, watertight concrete with a high strength and a high resistance to the action of sulphates. It may be noted that there are also two principal disadvantages in the use of pozzolana, namely, that the shrinkage on setting is increased (a slightly higher water/cement ratio is used than with Portland cement alone), and the initial strength of the concrete is slightly less; however, this fact is not considered a disadvantage in dam construction, as it rectifies itself as the age of the concrete increases and the action of the pozzolana is felt. The Pieve di Cadore dam, which is mentioned later on, was also built with a concrete in which ferro-pozzolanic cement was used. A study of the use of pozzolana, with particular reference to these two dams, was given at the Fourth Congress on Large Dams.†

The design of the dam was the subject of considerable study, the final result being achieved after theoretical analysis confirmed by extensive model tests. Considerable excavation was carried out on the right bank of the dam site, so that a symmetrical structure could be built; the only asymmetry in the completed dam is in the bottom 12m of its depth and at a widening of the valley near the top level of the dam on the left



Figs. 44 and 45—Lumiei Dam

* "The Most Recent Dams by the Societa Adriatica di Elettricita (S.A.D.E.) in the Eastern Alps," by Dott. Ing. Carlo Semenza, Paper No. 5771, *Journal I.C.E.*, Vol. 1, No. 5 (September, 1952).

† Fourth Congress on Large Dams, New Delhi, 1951. Paper R.74. "Efficacité de la Puozzolane ajouté aux Ciments destinés au Beton pour Grands Barrages et Application recentes en Italie," by Biadene and Pancini.

bank side for the last 15m of height. A symmetrical structure was thought essential; the model tests indicated that a symmetrical solution was a better one and the avoidance of twisting stresses due to asymmetry allowed a reduction in thickness, the resulting decrease in volume giving an overall economy, in spite of the extra area caused by the right bank excavation.

The peripheral joint between the dam and the "saddle" of reinforced concrete which transmits the thrust of the structure to the rock is of particular interest—it is typical of similar joints used for other recent Italian designs (the "dome" of the dam contained in this joint is completely symmetrical). Whilst construction is in progress, such a joint forms a hinge at the abutment, so that a direct thrust is transmitted to the rock, while the "green" concrete is undergoing a certain amount of contraction. On completion of the work and after sufficient time has elapsed for contraction of the concrete to have taken place, the joint is grouted. Provision has been made at Lumiei dam to allow further grouting in the future if it should prove necessary. The construction joints were also grouted on completion to ensure an even distribuion of stress across them; they were spaced 15m apart, horizontally, being curved near the edge of the dam to meet the peripheral joint at right angles.

During construction the River Lumiei flowed through a diversion tunnel, which was subsequently plugged with concrete; there is a pipe 1·20m in diameter in this plug, however, with a blank flange; in an emergency the blank flange could be blown out to empty the reservoir. There are three scour culverts at different levels and a spillway with five 10m openings in the crest of the dam; discharge from this spillway falls freely to the rock at the bottom level, which is clear of the structure itself owing to its overhang. It will be recalled that the scheme is for peak load generation, so that heavy spilling for long periods is unlikely.

The quantity of excavation for the dam totalled 63,000 cubic metres of rock, and the concrete 100,320 cubic metres, with nearly 4000 cubic metres more used to fill a deep crevice on the right bank near the abutment. A light mesh of distribution reinforcement was incorporated over both faces and the crown rim of the dam was also reinforced. The only access to the dam is along a narrow road cut out of the side of the Lumiei gorge, which is as sheer and rugged as the illustrations indicate for several miles downstream. Construction of the dam was completed at the end of 1947.

Lumiei dam is one of the finest examples of the Italian technique of cupola design which has been constructed up to the present. It was conceived and built, Dr. Semenza states, as a curved plate "like a huge triangular tile," completely symmetrical inside the peripheral joint and able to absorb, transmit and distribute all stresses to the rock foundations without sharp variations or discontinuity. It may not be without interest to give, by way of comparison, some brief details of a dam built more recently in France along similar lines. The Enchanet dam, Fig. 46, in France (Massif Centrale) was built between 1947 and 1951, being placed in service in October of the latter year. The effect of the peripheral joint makes a particularly interesting comparison in this case. Such a joint, Dr. Semenza noted in his paper, might still be considered an open question. Its use began with the Osiglietta dam (completed 1939) and in general its results had been excellent; it substantially avoided tension stresses in the area round it, thus resulting in an increase of compression on the downstream face, for which proper increments of thickness were provided near the abutments. The following abstract has been translated from an article in *La Technique des Travaux*, of January/February, 1952.

"The originality of the project (Enchanet) consists essentially of the form of the dam, which is a thin arch markedly sloped towards the downstream. Until now no dam of this kind has been built in France. The Italians have successfully built such dams, in particular the Comelico dam on the Piave. With similar characteristics to Enchanet dam, the latter was built in three months with a powerful installation of constructional plant. Its success encouraged French designers to propose two similar dams—Enchanet and Couesque, of which the construction has been successfully completed without difficulty.

"The principal idea may be outlined as follows: A horizontal arch submitted to hydrostatic pressure must have, to be of the minimum volume, an angle at its centre of about 120 degrees. An arch dam would then be considered as a series of rings thus defined.

"But if the centre of the dam is vertical, the upper rings, of which the radius is larger than the lower, overhang the latter, and the cross section becomes more and more corbelled out as the banks are approached. To ensure stability with the reservoir empty, the upstream faces must thus be supported by concrete filling; this extra volume is not only useless; but it increases the upstream radius of the lower and middle parts, thus reducing the angle at the centre and leading to a thickening downstream so as to keep compression stresses within the desired limits. Thus, an increase in volume of 20 to 25 per cent is arrived at, according to the shape of the valley. Furthermore, the extra concrete is submitted to tensile stresses.

"The remedy adopted for an inclined dam consists in placing the upper arches further downstream until the abutments are stable with the reservoir empty. Thus, a considerable inclination towards the downstream exists at the crown of the dam, but, because of the arched form, it is stable and not inconvenient. In this manner the barrage of Enchanet was evolved, giving an economy in concrete of 20 per cent over a dam of classical design.

"A possible criticism was that constructional difficulties would outweigh, to some extent, the economy in concrete, but this was not found to be the case, construction being straightforward, it being necessary, however, to concrete in horizontal layers, keeping the crown highest and the lifts on each side progressively lower, to ensure stability throughout each stage of the work.

"Another point was made the subject of a close study—the inclined blocks keyed together perfectly, apart from shrinkage due to hydraulic and thermal contractions of the concrete. This shrinkage had the effect of shortening the horizontal arches and tilting the dam towards the downstream, thus imposing a bending load on the vertical cantilevers.

"As would be imagined, a horizontal crack opened at the head of the intakes following a sharp drop in temperature. This crack was not a serious fault. It was carefully repaired and sealed and did not give rise to a leak when the reservoir was filled. In future works of this kind, it would perhaps be advisable to take up this movement at the base with a joint, equipped with a watertight screen.

"Another remedy would be to inject the construction joints under pressure, in several stages during construction so as to compensate continuously for the shrinkage, thus bending the vertical cantilevers towards the upstream, and producing a prestress favourable to the distributions of the loads by a technique similar to that which has become current in striking the centering of bridges.

"Thus conceived, the dam is 68·5m high, 230m wide, and has a crest radius of 104m.

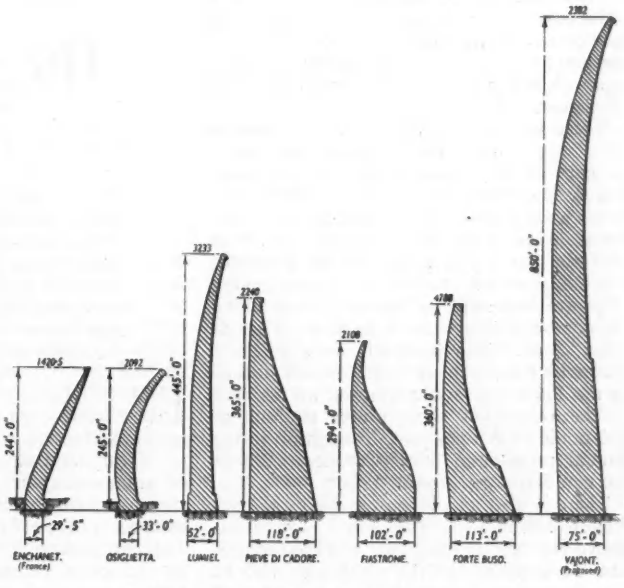


Fig. 46—Cross Sections of Various Dams

The maximum inclination of the upstream slope is 52 per cent and the concrete volume 65,000 cubic metres. The horizontal sections are circular rings; the thickness is 10·8m from the bottom to level 380 (about 20m of height), and then decreases to 2m near the crown. From level 380 to the crest the angle at the centre varies from 89 deg. to 113 deg. The abutments are thickened."‡

Whilst discussing the cupola design, it may be mentioned that Osiglietta dam is considered by many Italian engineers to be the most ambitious example of this school of design. This dam was illustrated in Fig. 38 last week, and its cross section is given, for comparison, in Fig. 46. It has a height of 75m and an overhang of 17m.

The River Piave

The two catchments to the west of the Tagliamento—the Piave and the Livenza—have been an important source of power to the S.A.D.E. for many years. The Piave has its source in the Dolomites, and flows

‡ The Couesque and Enchanet dams were described and illustrated in The Engineer of August 26 and September 9, 1949, respectively.

southwards to the Adriatic sea near Venice ; the Livenza takes a somewhat similar course to the east of it. The most recent development on the Piave is the Piave–Boite–Mae–Vajont project, which utilises a length of just over 20 miles of the Piave, downstream from the seasonal reservoir of Pieve-di-Cadore, which is close to the town of that name.

A diversion tunnel from the Pieve-di-Cadore reservoir passes under the left bank of the river for a distance of 24·6km and leads to the underground penstocks and power station at Soverzene. The tunnel has been built so that it either by-passes, or leads into, two reservoirs—Vajont and Val Gallina—formed on two tributaries of the Piave along this length. Also, the tunnel is joined about 3km from its start by an intake tunnel from the Boite river, and at about 16km by an intake tunnel from the Mae river which is now under construction. The Vajont reservoir has not yet been built, and the by-pass section of the tunnel is at present operative ; it will provide an appreciable seasonal reserve, and will be formed by a high arch dam. The Val Gallina reservoir is of interest in that it is close to the top of the penstocks, and serves as a surge chamber, as well as providing a convenient reservoir for daily and weekly regulation. It is formed by a cupola dam, and it has permitted a reduction in the capacity of the diversion tunnel above it, due to its own storage capacity, as well as considerably reducing excavation for surge shafts and expansion chambers.

There is a weir across the Piave close to Soverzene power station, which was built as part of the Piave–Santa Croce scheme. This development was completed in 1929, and consists of a diversion of the waters of the Piave at this point to the seasonal reservoir of Lake Santa Croce and to the Meschio, a tributary of the Livenza, and the generation of power in a series of power stations along the course of this river as far as the Livenza near Saerle. The provision of a total of 263 million cubic metres of seasonal storage in the Piave has now permitted an increase in the output of these power stations of 150 million kWh per year, in addition to the annual production of 650 million kWh at the new Soverzene power station.

There is also an old power station (Piave-Ansiei scheme) in the Piave catchment above the new development outlined above. The development of the catchment will be completed by a system of reservoirs and power stations on these upper streams and by a second system on the Piave catchment below the level of the diversion to the Livenza, which have been designed, but work upon which will not start until the Vajont dam has been built.

The present works have thus completely developed the Piave from a level of 830m above sea level down to Soverzene, and the Livenza from this point to where it enters the plain 13m above sea level. The production of power from this system is now 1520 million kWh evenly distributed throughout the year. When the whole scheme is complete, 1890 million kWh will be generated annually.

Soverzene power station is one of the largest of the S.A.D.E.'s installations and is used for frequency regulation of the company's transmission network. There are four 55MW 10kV, vertical Francis turbo-alternators installed, working under a head of between 284m and 225m. and giving an annual power production of 650 million kWh as mentioned earlier. When the project is completed the additional storage will allow a production of 800 million kWh.

In general construction the power station is similar to several recent Italian underground stations, being excavated in dolomite. There is a separate transformer chamber, with twelve 25MVA, 10/220kV, single-phase transformers in it (one standby unit is provided) and then a cable tunnel leading to a switching station above ground. From Val Gallina reservoir there are two diversion tunnels, each 5m in diameter and 2·5km long, leading to the power station. There are four surge shafts with a common expansion chamber at the top, about 120m in height and excavated in the rock above these two tunnels at the downstream end to allow for surge in the 2·5km length. There are then the valve chambers 120m below the surface of the rock, followed by the penstocks sloping steeply to the power station. The penstocks consist of two tunnels, each containing two lines of prestressed concrete pipes, 2·55m in diameter, set in concrete. Allowance was made for about 30 per cent of the pressure to be taken by the resistance of the surrounding rock ; practically, this factor is taken into account in computing the resistance to overloading. Steel penstocks replace the prestressed concrete ones in the last 15m or so next to the Francis turbines. The tail-race leads either to the Piave river or to the intake of the Piave-S. Croce system, as required.

The dams forming the two smaller reservoirs of the project at Val Gallina and Valle di Cadore are somewhat similar in their general conception and execution to the Lumiei dam; in the case of the Valle di Cadore dam, however, which is an arch dam, a facing of precast concrete blocks was provided on both faces for frost protection. There is a complicated system of tunnels and control gear associated with the Val Gallina dam, in view of its somewhat special mode of functioning mentioned above. This dam is of cupola design, with a pronounced overhang, and is remarkable for its chord/height ratio and various points such as the reinforcing of the right abutment.

Two schemes are being investigated for the proposed Vajont dam. The Vajont gorge is exceptionally steep, and a dam of considerable height is necessary to give an appreciable storage capacity, and a dam of either 204m or 255m in height is being considered. The higher one is shown in cross section in Fig. 46. It is expected that a construction will be started in a few years.

(To be continued)

The Training of Radiologists for Industry

By J. C. ROCKLEY

This article is based on a paper read by the author at the Summer Meeting of the Industrial Radiology Group of the Institute of Physics at Sheffield in July, 1952. It illustrates the need that exists for training facilities in industrial radiology and traces the causes of the present lack of such facilities. Reference is made to the proposals of the Industrial Radiology Group for the creation of a recognised course of training and a qualification in this subject. Suggestions are made to show how such a course could be organised on a national basis and a syllabus suitable for this purpose is discussed.

INDUSTRIAL radiology has become established during the past decade as an individual section of applied science. During its history and development over a period of some thirty-five to forty years it has shown itself to be an acceptable and reliable method in the field of engineering inspection. This reputation has been built up largely on the sound foundation of thorough investigation pursued by the pioneers in the subject. Industrial radiology, while still remaining a specialised subject, is now fast coming into more general use with the result that there is an increasing need for training facilities and instructional courses in its applications and techniques. Little has been done in the past to deal with this question and the somewhat surprising situation still exists where it is at present impossible to obtain any recognised form of training or qualification in this branch of technology.

There need be little doubt about the urgent necessity for the inauguration of a nationally recognised and comprehensive course of training in the subject. The increasing use of radiography has made it virtually impossible to obtain suitably trained people for the posts that have become available. The same condition obtains when it is necessary to find replacements caused by the normal wastage of staff from established positions. The only alternative is to fall back upon a short term and specialised course of training to which selected individuals can be sent. There is, however, a very limited intake of students to such courses, which are few in number. In addition, while such courses do much good they are subject to certain defects. They are limited in duration and therefore in scope and cannot in the time available give the students any comprehensive experience. These short term courses are best regarded as refreshers for those already acquainted with the subject ; they do not diminish the need for setting up a fully comprehensive and nationally accepted course of training.

It cannot be over-emphasised that it is economically unsound to employ inexperienced and untrained personnel on a form of work that calls for a high degree of skill and specialised knowledge. An incorrectly exposed radiograph can be a specious and false piece of evidence the acceptance of which might easily be the cause of the failure in service of a costly structure ; at the best it is an expensive process to repeat the examination when its original fallacy has been revealed. Consequences of this kind can be avoided only by employing skilled operators who are fully trained in the subject.

Training in Relation to the Development of Industrial Radiology

The present lack of training facilities would appear to be the natural outcome of the progressive but uncontrolled development of industrial radiology over many years. If the present situation is to be tackled in an imaginative and satisfactory manner and the subject to be seen in its correct perspective, it is necessary to examine the manner in which this problem of training

was dealt with by earlier workers in the field.

When radiography was first taken up by one or two bodies, there were no trained radiologists who could take over the new process. The process itself was something of a mystery, but obviously had a scientific background. It was given, therefore, to a physicist, or to a works chemist or metallurgist to see what could be done with it, provided it did not interfere too much with his normal duties. It was, in fact, a side-line that possibly held a few limited applications. These early workers were thus entirely self-taught. They made their progress and developed their skill by the simple expedient of trial and error methods. In this way they individually acquired a high degree of skill that was limited only by the capabilities and characteristics of the apparatus then available. Uses for the method were developed and as its applications were extended the knowledge so gained was passed on to colleagues. Skill and experience were transmitted in this way from one individual to another and eventually became incorporated in the reputation of a particular firm or organisation. This seems to be true particularly of the practical aspects of industrial radiology. Many books have been printed on the theory and physics of X-rays, but for some reason that it is difficult to elucidate very few have appeared that deal in a like manner with the essentially practical side of the subject. There thus existed a coterie of knowledgeable radiologists at this time to whom reference could be made when problems in radiographic inspection arose. A firm that became a new entrant to the field of radiography could generally arrange for a member of its staff to be sent to one of the established laboratories for training. This system suited the needs of the times. It was adequate for the purpose intended, but by present conceptions was very restricted in outlook. Taking the country as a whole, the training given was most certainly not uniform in content or standard.

The history of the last decade shows an entirely different attitude to training requirements. The progressive but leisurely development of industrial radiology in the 1920s and 1930s changed overnight to one of rapid expansion due to wartime needs. Established uses of radiography were vastly increased and new applications were developed. An immediate need arose for trained staff to undertake these duties, not only as radiologists but also as inspectors who were concerned with the use of radiography as an inspectional tool. This demand was satisfied by instituting short training courses devoted to the requirements of an individual field. They were not designed to be comprehensive and in practically all instances were restricted to the staff for whom they were intended. They satisfied an urgent need, however, and at the same time gave to those concerned with organising them an opportunity to visualise for the first time the requirements of a full-time course.

Since those days there has not been a great fall off in the use of radiography. The volume of the work has perhaps been reduced, but the number of active laboratories has been maintained and increased. The recent introduction of radio-active isotopes has given a new impetus to the method. The rearmament programme has increased the production of materials on which radiography is a mandatory part of the inspectional system. These conditions, and others, culminate in a state of affairs in which industry is confronted with the need for trained radiologists. This need cannot, at present, be satisfied. The old methods of training are not suitable, nor are they in fact available. Laboratories that formerly might have undertaken the training of individual students are now too busy to take on such work. Waiting lists are the order of the day on those courses that are in being.

The Present Situation

Industrial radiology is now a highly organised method of inspection. The tools that it uses have become complex pieces of scientific apparatus requiring careful handling. In the field of gamma-radiography, this latter point is particularly true, since radiation hazards are avoided chiefly by the common-sense and knowledge of the operator. The applications of radiography are no less highly developed and scientific. The use of the method, even in the more routine instances, requires a high degree of skill and understanding on the part of the radiologist. If these qualities are lacking, the results of radiographic inspection are at once suspect and unreliable. It is a subject, therefore, that requires skilful and expert training. Despite this fact, it is common to-day for individuals to be classed as industrial radiologists who have had little more than a nodding acquaintance with both the theory and practice of the subject. This is a condition which, if allowed to continue, will jeopardise the status and value of radiographic inspection in industry. It opens the door, if not to quackery, at least to the continuance of an inferior standard of work.

The reality of this situation is illustrated by the fact that those bodies concerned with the use of radiography in vital fields, for example, the Admiralty, the Aeronautical Inspection Directorate, and Lloyds have found it necessary to institute their own examination or training schemes to ensure that radiography of an acceptable standard is obtained. There has been also a parallel case in the field of medical radiography. In medical radiography there was set up in 1921 a training and examination scheme, and for reasons identical to those just mentioned. This scheme now ensures that all medical radiographers have had adequate practical experience, have followed a prescribed course of training, and have gained a nationally recognised qualification. There is a need in industry for a similar method of qualifying. As in the medical field, the training obtained should equip the student to take on all the duties of a radiologist in charge of an X-ray department concerned in any branch of industrial radiology, and to do so in a skilled and competent manner. The successful completion of such a course should carry the award of a suitable diploma.

The Organisation of a Training Course

The training and examination requirements of medical radiography are well organised on an international basis by the Society of Radiographers. The examinations held by this Society are recognised throughout this country and abroad as a standard qualification in the subject. The Society of Radiographers has also established a series of recognised training centres at hospitals in Great Britain and in other countries of the Commonwealth where instruction can be obtained. There is at present no comparable body in existence in Great Britain that could regulate similarly the training needs of industrial radiography. The lack of such an organisation has been recognised, however, by the Industrial Radiology Group of the Institute of Physics. This group is the only body in the country that is actively engaged in a serious manner in advancing the standards, scope and interests of industrial radiology. It is acutely aware of the consequences of the present deficiences in training facilities. During the past year it has examined closely the training problem in this field, and reached a decision to initiate a plan for the organisation of a nationally accepted training course in industrial radiology. The scheme suggested was a recommendation to the Institute of Physics, as the parent body of the Industrial Radiology Group, to approach the City and Guilds of London Institute with a view to examining the feasibility of setting up such a course. The award of a City and Guilds certificate was envisaged at the completion of the course and after passing an appropriate examination in the subject. The results of this suggestion cannot yet be forecast, although it is known that the City and Guilds of London Institute has established an exploratory committee to examine the question.

It is one thing to suggest that a course of this sort should be set up, however, and quite another thing to show convincingly that it is necessary and justified. The exploratory committee of the City and Guilds of London Institute will wish to satisfy itself of the need to provide classes. This must be considered, not only from the point of view that tuition is desirable because of the need to improve the present standards of radiography, but also in the sense that there must be a sufficient number of students presenting themselves annually for training to warrant the continued existence of the scheme.

Training Centres and Instructors

It is opportune at this juncture to study how the course could be housed and staffed with instructors. The course itself must obviously be brought to the job. It is inconvenient and inefficient to arrange for it to take place in a single location that is remote from the places of employment of the intending students. Many of them cannot be spared from their work to attend protracted training courses. A simple solution would be to set up training centres in the local technical colleges in those regions of the country where industrial radiology is widely used and to organise the courses as part-time day or evening classes.

The use of technical colleges in this way presupposes that they are equipped to take on work of this sort. In most instances this is probably not the case, and one of the problems to be solved will be to see that suitable equipment is made available to them. This will undoubtedly be a difficult point. At least two X-ray units will be required at each centre if a class is to be satisfactorily conducted. Dark rooms and processing equipment, and other ancillary apparatus will also be required. It will, in fact, be necessary to install an X-ray department complete in all details and modelled on the lines of those found in industry. The support of the education authorities must be won if these requirements are to be carried out, not only financially but also in regard to finding space in college premises that are already overcrowded.

There is also the problem of finding lecturers to conduct the course. Few technical colleges will have on their staff people who are qualified to lecture on the practical techniques of radiography. It will undoubtedly be necessary to call in practising radiologists of repute to act as part-time staff to fill this gap. As a matter of fact it is common practice in other instances to do this in subjects having distinctly practical applications. It ensures that the correct bias is maintained in the course, and that the prac-

tical techniques do not become submerged in a too academic approach. The theoretical aspects could conceivably be dealt with by the staff of the physics departments of the colleges provided that the instruction given is related to the practice of radiography.

The Syllabus—Preliminary Considerations

It will be necessary to model the syllabus on comprehensive lines if the course is to be of value. It must treat adequately both the theoretical and practical aspects of the subject. A difficulty on the practical side is created by the very wide range of applications of radiography. The inclusion and complete study of each in the course would make it unwieldy and of excessive duration. It would thus appear to be a more workable arrangement to frame the syllabus around the requirements of the two largest fields of application, i.e. the inspection of castings and welds, and to study these uses thoroughly in every way. The less used applications and specialised techniques could then be introduced in a manner that acquaints the student with their purpose, and gives him an insight into the principles involved, rather than attempts to make him an expert in their use. Similarly the same can be said for other methods of non-destructive testing, which will require mention because of their complementary nature to radiography. The greatest need lies in the two main fields of radiographic inspection, and it is therefore reasonable to suggest that the course should be devoted to them at its inception. Modifications and additions to its structure—even to the extent of forming a separate and more advanced course—can always be made at a later stage, if and when necessary.

This is not the only problem that will confront those concerned with compiling a syllabus, even before they start to outline the detail of its content. It is necessary, for instance, to decide at the outset for whom the course is intended, and the standard at which it is to be set. While these are obvious and fundamental points, they unfortunately do not solve themselves as readily as they present themselves. Ideally, candidates for the course should come from a technically educated class, and should be of a standard equivalent at least to Inter. B.Sc. At present, however, the work of the industrial radiologist is carried out by individuals whose educational standard as a class varies over an exceptionally wide range. At one end of this range will be found those who possess little in the way of academic qualifications or training, but who have a fund of wide experience on which to draw. Candidates of this type must not be disregarded. Many of them produce excellent results because they are blessed with that essential virtue, a feeling of compatibility for the work. At the other end of the scale are found graduate metallurgists and physicists. Radiography is for these people more often than not a part-time occupation, because staff of this calibre are generally more concerned with research or administrative duties. They can, however, be lacking in a knowledge of the applications and practical techniques of radiography even if they are equipped with the necessary theoretical background. It is necessary, therefore, to produce a course of training that is suitable in content and standard to this widely varying educational level.

It would appear that the initial approach to this problem is to plan the course with the younger and less qualified type of person in mind, the individual who is a junior in an X-ray department. Provided that certain reservations are made concerning the minimum educational standard required, the theoretical aspects should be set at a level that is somewhat above this standard. The older man has at least his experience of the subject to guide him; the graduate will not necessarily be wasting his time by working at this level, since it will probably act as a refresher in a field with which he is not now familiar. The practical side can be treated mainly in one way only, and here the two types of individuals should find themselves on common ground. It is suggested, therefore, that in establishing the conditions of entry to the course an educational standard of not less than the ordinary level of the General Certificate of Education in English, Physics, Chemistry and Mathematics should be expected of the students, or evidence of ability to this standard through the possession of a similar qualification. This would conform to the current practice in medical radiography, where a comparable standard has been found to be the minimum qualification necessary to enable the student to obtain a grasp of the fundamentals of the subject. In addition, the candidate should be in a position to gain practical experience of at least one branch of radiography during the course of his normal employment.

The syllabus for this course of training must reflect the fact that radiology is, above all subjects, a complex mixture of physics, chemistry, electrical engineering and practical techniques. In addition, it must also include references to the theory, practice and terminology of the field in which radiographic inspection is applied. These requirements must be carefully balanced and a reasonable relationship obtained between the essential theory and the common practice of the subject. This relationship should give a bias towards the practical aspects in so far as they should be thoroughly explored and exhaustively treated. No neglect of the theoretical side of the subject is implied by this bias. It must be covered to give an adequate understanding of the whole process of radiography. This is where the greatest difficulty will arise in setting the most suitable standard of instruction. This ensues from the fact that the fundamental physical principles involved in the generation, control and use of X-rays and gamma-rays cannot be absolutely comprehended without a specialist's knowledge of physics. A similar condition exists in regard to the chemistry involved in the photographic aspects of radiography. In the type of course envisaged, the exposition of these fundamentals is best taken no further than to a stage where they continue to bear a direct relationship to the effects observed in practical radiography. To go beyond this point will result in a confusion of ideas. The course should avoid becoming over-academic. Its aim must be to turn out competent radiologists, not qualified physicists.

The Syllabus—Theoretical Aspects

The student who has been accepted for such a course can be expected to have acquired a reasonable understanding of the fundamental principles of heat, light, sound, electricity and magnetism. There is much in this background that is apposite to the study of radiology. The early part of the syllabus could be devoted with value to a revision of these factors. Examples of those features that fall into this category are the geometry of shadow formation, the formation of umbra and penumbra, and the effect of the inverse square law upon the intensity of radiant energy. Elementary principles of these types should not be neglected since they form the practical basis of every radiographic exposure.

Opinion will vary as to the best order in which to present the more advanced sections of the theory of the subject, although there should be little controversy as to its content. It is essential that the student should obtain some knowledge of the manner in which his apparatus and materials function, and be well aware of the nature and properties of the radiations that he uses. A case exists for treating these two subjects in this order and to deal with the design and construction of X-ray apparatus immediately after the revision of the earlier work. If this system is adopted, the syllabus would then proceed to a study of a.c. electricity, the production and control of high voltages, and the conduction of electricity in vacuum tubes. It should aim at acquainting the student with those general principles common to the functioning of any type of X-ray set. This will extend naturally to a consideration of the design and construction of industrial X-ray units. All radiologists should understand the manner in which their apparatus works. The turning of a knob or the setting of a switch should be more than an action associated with the front of a control panel. It is to be expected that the radiologist is aware of the way in which the various controls affect the working of the unit and influence the production of X-rays. The circuits of modern X-ray units should be studied and compared, and guidance should be given in the diagnosis of operational failures and breakdowns. This is probably sufficient for the radiologist employed in a works laboratory. He is generally within easy reach of a service engineer to whom he can telephone a technical description of the symptoms and possible causes of failure. There would appear to be little need to educate the works radiologist to a point where he would usurp the functions of the service engineer. That is one point of view. There is, however, the case of the radiologist working on a remote site well removed from the immediate amenities of a repair service. A radiologist in this situation, it would appear, must be capable of keeping his apparatus in working order and be able to make minor repairs and to fit replacement parts. Obviously, therefore, his training in apparatus construction must be more thorough than that of his colleague in the laboratory.

It is desirable that the student should acquire a thorough appreciation of the nature of X-rays and gamma-rays, of their properties and the effects that they have upon matter. The more complete the student's understanding of these points the better will he comprehend the behaviour of the medium with which he is working in the various techniques of practical radiography. A lucid account of these characteristics in the early stages of the course will be found to have been of benefit when the time comes to deal with their practical applications, as, for example, in the functioning of intensifying screens or the principles and operation of radiation monitors. It is possible to give a clear picture of these principles and yet at the same time to relate them to radiographic practice. The lectures must obviously include a certain amount of theoretical discussion as well as an explanation and description of the points involved. They should, however, be combined with carefully prepared experiments that the student can carry out himself. If this is done, the value of the course is infinitely increased. This can best be illustrated by referring to a specific example concerned with scattered radiation.

This is a part of radiographic theory that is difficult to explain in a convincing manner

by lectures alone. The problem is to enable the student to appreciate, not only the theory, but more important the detrimental effects of scatter in radiography. He must be able to recognise the presence of scattered radiation even in its most insidious forms. A method found most helpful in creating this awareness calls for a simple down-to-earth experiment based on the "before" and "after" principles more usually applied to the illustrations in advertisements. An exposure is first made on a suitable specimen so that all the detrimental effects of scattered radiation are revealed in the radiograph, but in such a way that the untrained observer might consider the result to be reasonably satisfactory. A second exposure is then made under identical conditions but with various scatter-eliminating devices added to the set-up. The argument presented to the student is that if scattered radiation were present in the first radiograph, the second exposure of similar duration should result in a less dense radiograph because of the removal of the scattered radiation in the new set-up. The exposure is made and there is, of course, a very great reduction in the photographic density. This in itself can be a very illuminating demonstration which is made even more convincing by the third and correct exposure showing all the defects and penetrameter steps in sharp outline and with high contrast.

These details will be obvious to the experienced radiologist since he applies them as a matter of routine. To the inexperienced student, however, the results of such an experiment are both enlightening and obviously associated with the routine practice of radiography. He is left in no doubt as to the truth of the theory and to the bearing that it has upon the actual job. There is an essential need for a combination of lectures and laboratory experiments in the theoretical side of the course.

One further feature that should be mentioned in this broad survey is the use of gamma-ray sources. A section of the course must be devoted to this topic if the syllabus is to keep abreast of modern developments. Indeed, it is not unlikely that many students will come from laboratories where gamma-ray sources only are used for radiography. The section of the course devoted to the use of gamma-rays should include an elementary treatment of radio-activity. The natural and artificially produced sources should be considered, and their characteristics explained to ensure that the student is aware of the individual nature and useful field of application of each type of source. A most important feature in this section will be the inclusion of clear account of the relative values of X-rays and gamma-rays in radiography, and of the complementary nature of these two types of radiation.

The use of gamma-rays brings in the need to consider radiation hazards and safety measures. This subject is of considerable importance and warrants individual treatment. It should be dealt with from the point of view of both gamma-rays and X-rays. The student should be instructed in the fundamental differences in protection methods when dealing with these two types of radiation. Radiation monitoring and measurement can be included in this section, together with a study of the current safety regulations and recommendations. It is pertinent to this section of the course that the laboratories in which the work of the course is carried out should be beyond reproach in respect of safety conditions. This is a feature that is too often neglected. It must be remembered that the average student will be employed in a laboratory or on a site where the somewhat makeshift, but albeit safe, conditions of the experimental laboratory would be a menace. It is necessary to cultivate in the student a natural habit of care and regard for safe working conditions.

The Syllabus—Practical Aspects

Two problems confront the student radiologist at the outset of every radiographic examination that he is called upon to undertake. He must be able to select, first, the most suitable method to satisfy the requirements of the investigation, and secondly, be able to recognise the radiograph that is correctly exposed for this purpose. These are fundamental issues on which the validity of radiography depends. The syllabus must, therefore, be so framed that these aspects are dealt with in a thorough and practical manner.

It is clearly insufficient to allow the practical side to consist simply of a series of exercises in which the student is made to radiograph a number of different types of welded specimens or varied shapes of castings. This type of treatment, while it might develop some degree of manipulative ability, does nothing to give the student an appreciation of the applications and limitations of radiography; nor is it likely to encourage the need to work methodically, which is of such importance in any form of radiographic examination. The student should be forced to think for himself and always to bear in mind the ultimate purpose and requirements of the examination. This is vital, since these requirements will necessarily influence the approach that is made to each problem, and the method that is adopted to satisfy them. Equally important, the student must be able to recognise the occasion when radiography can be of little use, and he must be capable of suggesting the use of another method of non-destructive testing in such a case.

Methods for the examination of a casting or welded specimen will vary according to whether the coverage of the part is to be complete or partial, or whether the highest degree of sensitivity is necessary or not. It is not practicable to give instructions in techniques to suit all these variables in the lectures and experiments of a training course. The cases where they arise in practice are all instances for individual consideration once the requirements of the examination are known. It is far better, therefore, for the syllabus to set out to give instruction in the complete examination of a specimen and to the highest degree of sensitivity. Once the student is aware of how this standard of examination can be obtained it is an easy matter for him to alter and modify his methods in those instances where a different order of examination is more suitable.

The opinion is often expressed that this branch of radiography is an art, and that one either possesses the knack of being able to master it or not. Undoubtedly many radiologists have an uncanny faculty of adroitly selecting just the right view for a particular purpose. While this apparent ingenuity might support this opinion, on analysis it will be found that radiologists with this natural flair are working subconsciously to a set of rules. The choice of views in any radiographic examination can in general be based on certain prescribed rules and geometric principles that can be expounded. Every casting, no matter how large its size or whether it is cast in light alloy or dense metal, is nothing more or less than a collection of simple basic shapes or forms arranged in a particular grouping. This principle is also true of welded parts. If these basic shapes are considered individually it is a fairly straightforward matter to determine how each one is to be radiographed in regard to the number and direction of the views needed to cover it completely. These basic requirements can be illustrated without difficulty on the blackboard, and can be given to the student as a standard guide. In the early stages of instruction simple specimens embodying one or two of these shapes can be used for radiography. Gradually the complexity of the specimens can be increased, but in all cases the basic requirements laid down by the rules should be followed.

There is obviously more in the examination of castings than the selection of the views to be used, and that the choice of view is frequently dictated by some consideration other than the shape of the object under examination. There is also the danger that a slavish adherence to such a system will cause the student to turn out methods that are nothing but an academic nightmare and impracticable in the extreme. It is necessary, therefore, to analyse the methods produced and to show how in many instances when one area is being radiographed in the prescribed manner a second zone is satisfactorily and simultaneously examined as an incidental feature. This would obviously allow of a reduction in the theoretically required number of views to produce a more workable and, at the same time, adequate method of examination. When coupled with guidance of this sort this method of instruction has the great virtue that it makes the student approach the problem of technique compilation logically and methodically. The haphazard selection of views is avoided, which at the best arrives at a satisfactory solution only occasionally and fortuitously. The student's work becomes orderly, and the most awkward of specimens, whether large or small, suggests through its own shape the construction of the method to be used in examining it.

This need for method in radiography can be stressed in other aspects of the subject, and many of them lie in the preliminary steps that are taken before an exposure is made, e.g. the positive and foolproof identification of radiographs, particularly in those cases where the image is symmetrical in form. It is not only the student who falls into this trap, for most radiologists have misplaced their confidence at one time or another in the ability of a letter *A*, *H*, *T* or *X* to indicate the correct orientation of a radiograph. Accuracy in setting-up for an exposure, and the realisation that the chosen angle of the beam is found only at the centre of the field of radiation are other points of this nature. Simple enough in themselves, they are nevertheless the basis on which good radiographic results are formed. They must be given a place amongst the more technical and theoretical sections of the course if the student is to gain competence and the ability to examine his own work critically.

The Syllabus—Interpretation and Reporting

The radiologist, like any other investigator, must be able to present the results of his work clearly and without ambiguity. A failure or inability to write a report of this nature undermines the whole value of radiographic inspection. Experiences in the past tempt one to add that there might even be a case for the inclusion in the syllabus of a brief course of instruction in elementary drawing and the Queen's English!

The first essential will be to instruct the student in the technique of viewing radiographs. The act of examining a radiograph must be shown to be more than a hurried glance, after which the film is hurled into a tray. It should consist of a thorough

scanning of the film in conditions that will enable the task to be undertaken comfortably and without distraction. These requirements are by no means fussy or academic. Film viewing is tiring work and unless performed in ideal conditions can lead to inattention and oversights.

The second essential is to coach the student to interpret the shadows formed by the specimen itself as distinct from those formed by any defects that may be present. He must be able to convert mentally the two-dimensional radiograph into a three-dimensional solid object, and must be able to visualise how the shadows of each plane and section in the specimen were projected into the pattern shown in the radiograph. It is patently impossible to instil an awareness of these factors by a single lecture. A better method is to examine and discuss them as they arise during the practical work of the course, and to create an instinctive ability to recognise them in this way.

The third step in the interpretation of radiographs embodies the recognition of the indications of casting defects. This can be taught through a study of radiographs displaying the characteristic features of each type of defect. It is of benefit if this part of the instruction can be supplemented by an examination of the actual defects themselves in the sectioned specimens, in order to acquaint the student with their metallurgical nature. In addition, care should be taken to use the recognised terminology in describing the defects.

It must be recognised in the end that interpretation is not simply a matter of distinguishing one shadow from another. Any fool with a guide book beside him can do that. The essence of it lies in being able to present this information in a form that gives the fullest details about the nature, extent and location of the defects seen. Additionally, the report should illustrate clearly the manner in which each radiograph has been obtained. Such reports in industry are frequently circulated among individuals who, even in these enlightened days, are unacquainted with radiographic procedure and evidence. They should therefore be framed to be understandable to anyone to whom they are submitted. Report writing on these lines could be fostered in the course by a supervision of the students' methods of writing up the results of their practical work.

It is considered that a syllabus of the kind discussed would necessitate a course of at least 400 hours' duration. This is largely due to the need for an adequate amount of practical work which could not be incorporated satisfactorily in a shorter period. The suggestions made are intended to illustrate one possible way of handling such a course. No matter how the problem of training in industrial radiology is tackled it is essential it should be dealt with on a basis that will ensure a uniform standard of training throughout the country. Whether some form of nationally accepted training comes into being remains to be seen. If this aim is to be attained it will require much hard work and organising ability to be put into it, particularly in the early stages. Its recognition by the authorities will not come immediately but only after it has proved itself to be a serious course of study calling for high standards of theoretical knowledge and practical ability.

It is a pleasant duty to record the kind help of Mr. Denley, of the Society of Radiographers, in supplying the information concerning the organisation of the training courses in medical radiography, and Dr. V. E. Pullin, for his assistance and advice.

Admiralty Test House for Gas Turbines

A new test house for naval gas turbines has been completed at the National Gas Turbine Establishment, Farnborough. In a larger steel-framed concrete building there is a test bay 100ft long by 40ft wide. Here engines for naval ships and coastal craft up to 10,000 s.h.p. can be given trials in conditions closely resembling those to be found at sea. Provision has been made for expansion of the test bed in the future, if required.

THE gas turbine test house at Farnborough described in this article is of steel-framed concrete construction nearly square in plan (Fig. 1). It covers an area 100ft by 94ft and is so orientated that exhaust gases are discharged on the leeward corner of the prevailing wind and inlet air taken from the opposite corner well above ground level, so as to be relatively free of dust. The flat roof of the building stands 50ft above the ground.

The main part of the building is the test bay (Figs. 2 and 3), which runs the full length (100ft) from floor to roof and is about the beam of a frigate (40ft). It contains the test bed, and has a temporary wall at the south end so that it and the test bed can be extended if necessary. All walls and roof are lined with slabs of compressed fibre to damp noise. On the ground floor to the east side of the test bay are a fuel oil and lubricating store, a pump room which is open on one side to the test bay and which contains the fuel and lubricating oil auxiliary machinery, including heaters, coolers, &c., and an electrical room with switchgear, transformers, rectifiers, emergency diesel generator and rotary converter. On the first floor to the east side of the test bay is a flat open roof supporting the exhaust duct and splitters, as well as a hut over the pump room containing two gravity tanks, one for fuel oil and the other for lubricating oil. On the first floor to the west side of the test bay are the control room and three offices.

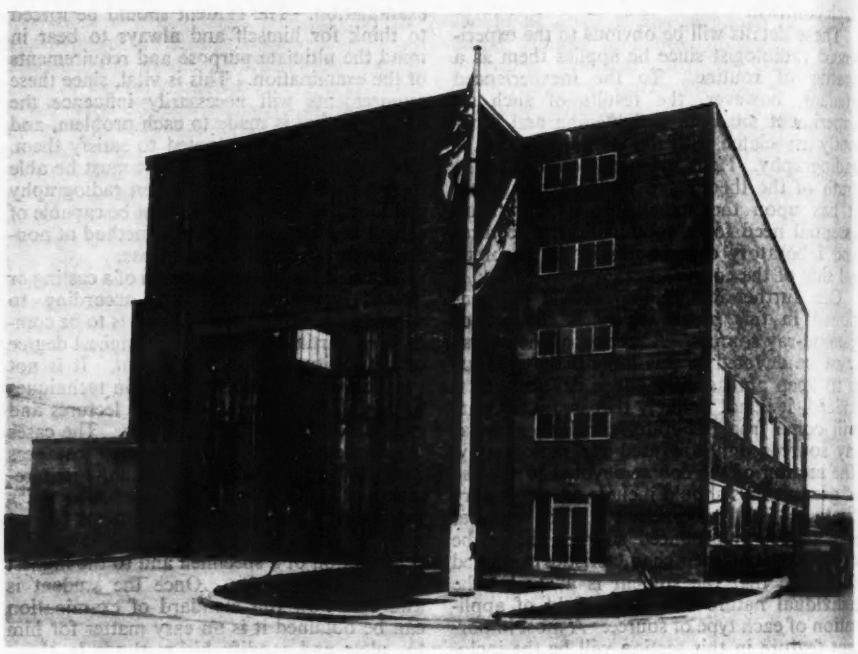


Fig. 1—Admiralty Gas Turbine Test House

Plant design was started in August, 1948, when Captain (E.) W. K. Weston, R.N., was appointed to the Establishment. He has since been relieved by Captain (E.) H. Farquhar Atkins, R.N. As the requirements for testing large gas turbines, particularly in adaptation to naval or marine use, necessitated broaching fresh ground and peering into a very dimly lit future, design involved considerable ground work and imagination. The scheme was shaped in sufficient details to "lay the keel" in May, 1951, when work was commenced on the test bed. The building around it was started soon after. The construction of the building and installation of standing machinery was executed mainly by contract supervised by the Ministry of Works.

Test Bed

The test bed was modelled on a larger one built at Pametrada. It consists of a mass of heavily reinforced concrete, 6ft deep, carrying four parallel lines of cast iron girders. Each line is made up by nine "I" section girders each 8ft long, set end to end with a 1½in space between. The top faces of the girders are 15in wide and their centre lines are set 3ft apart. The girders, in addition to being grouted in to half their depth, are bolted down by 2in bolts of considerable length which extend down into the concrete and are secured to the actual reinforcing. The whole structure, therefore, is of very solid construction and its great weight should prevent vibration troubles. It is sunk in the ground so that deck plates on either side level with it form a convenient floor for the test bay, graded to the approach road outside. The girders were carefully levelled before being finally bolted down so that every part of them was within five-thousandths of an inch of datum level and that the average level of each girder is within two-thousandths. Slots are provided at frequent intervals along the flanges of the girders for engine holding down bolts up to 2¼in diameter. A 20-ton electric crane and a 1-ton hand crane serve the whole length of the test bed and the loading platform.

Air Inlet

Air is drawn through a series of portable splitters to reduce noise and thence by way of a

bank of dust filters (down to 10 microns) to a venturi nozzle consisting of throat, measuring section and diffuser. It then continues through steel trunking of section 5ft square into and along a distributing shaft high up along the length of the test bay, take-off pieces interchangeable in position with simple straight-through pieces, composing the distributing shaft. Ducting shaped to suit the size and position of the intake to turbines on the test bed is led down from the take-off pieces. So far as possible, "cascades" are fitted to right-angled bends to reduce eddy losses. The actual Venturi throat with its measuring length and diffuser, and the parts immediately preceding it (the air inlet entry piece, which collects the air which has passed through the filters, and a length 6ft in diameter containing a honeycomb section for straightening out the flow prior to entering the throat) are made of wood. All parts of the inlet trunking is fitted in the common duct at the end of the diffuser.

Dynamometer and Water Circuit

A Heenan and Froude double-ended reversible water brake type dynamometer, mounted on a stool, capable of being sited as required on the test bed, is provided to absorb load up to 10,000 s.h.p. in either direction. Its maximum permissible speed is 1100 r.p.m. and the slowest speed at which the full horsepower can be absorbed is about 620 r.p.m. Remote control of the back-pressure valves, which regulate the load, is arranged from the control room, and a hydraulic weighing gear also enables the torque to be measured from the control room. There is an oscillator in the weighing gear to prevent inaccuracies in readings due to sluggishness in the transmitting and receiving pistons and in the long lengths of piping connecting them. The brake is designed to stand, within certain speed and power limits, an instantaneous reversal of torque. Within the short time (visualised as little as fifteen seconds) required for the system to slow down, stop, and speed up in the reverse direction, a change-over cock enables the weighing gear to recommence registering, although it will not register at the actual moment of reversal. The brake can be run with its axis inclined at any angle up to 11 deg. with the horizontal, to enable it to test engines which are installed at a rake.

A 12,500-gallon header tank supplies water to the brake at a constant head of about 40ft, and the brake drains to a hot sump through a 14in pipe. The water is then pumped to a cooling tower and again from the cooling-tower pond to the header tank. An overflow from this tank to the hot sump, of ample capacity, enables the head to be kept constant despite varying requirements of the brake, and both pumps and "key" valves in the system are controlled from the control room. The pumps and cooling tower are designed to give a margin over the maximum requirements of the brake, which are 64,000 gallons per hour cooled from 140 deg. Fah. down to 100 deg. Fah., and the 6000 gallons per hour referred to under "exhaust" (which is, of course, supplied, but not returned). Float-controlled, make-up valves on this and all other cooling-tower ponds mentioned in this article are designed to give ample compensation for evaporation and other likely losses.

Load Tank

For absorbing the output of alternators driven by gas turbines under test, arrangements have been made to provide a variable load for alternating current up to 440V and 1250kW by means of a load tank, situated in the open with switchgear in the electrical room. The load tank is divided into four equal portions, three of which have a common water level kept steady by float-controlled supply, the fourth level being varied by two pumps which are controlled from the control room. Current from the alternator is fed to a main switch, controlled from the control room, and thence to four switches, one to each quarter of the tank, locally controlled, but with indicators in the control room, which is connected, of course, by telephone. Thus, it is possible for the control room to vary the load either in steps throughout the whole range or gradually through a chosen range. Space has been left for further switchgear to connect to the grid in future, if required.

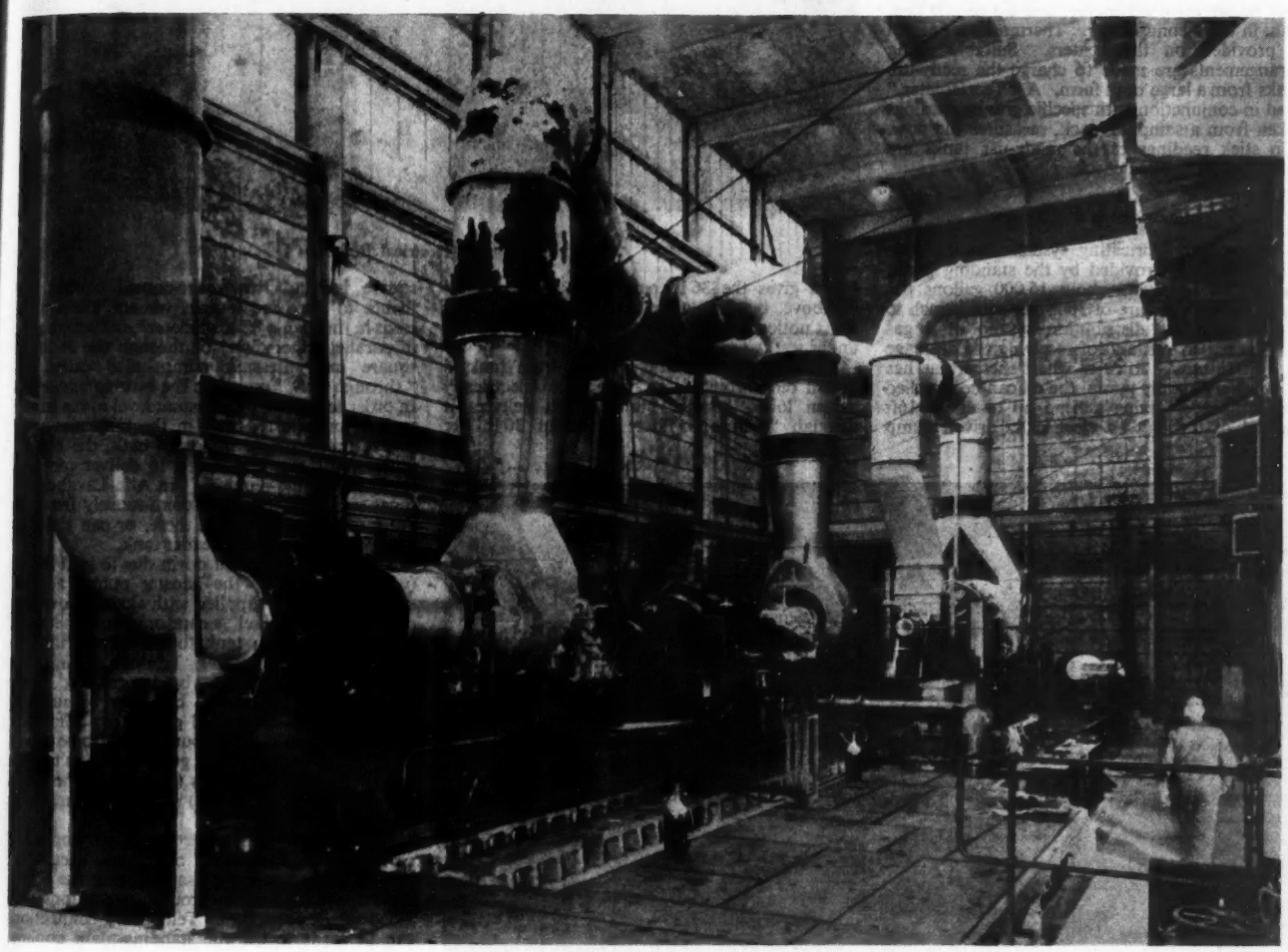


Fig. 2—Gas Turbine Test Bay

which are outside the test bay, both wood and steel, are supported on rubber strips to damp noise. There are two interchangeable venturi assemblies, one having a 36in throat for measuring mass flows between 150 lb and 50 lb per second, and one with a 28in throat for smaller mass flows.

Exhaust

Exhaust trunking from each turbine on the test bed is led up to a common duct, which takes the gases out of the test chamber to a diffuser and set of splitters on the flat roof to the east of the test bay. Two water injection pumps are incorporated in the system to assist in further silencing; they are fed from a pump which draws water from the dynamometer header tank, a maximum of 6000 gallons per hour at 100 lb per square inch being provided. Bellows pieces allow expansion in the individual leads of trunking from each turbine, and an expansion gland

Fuel System

Fuel stowed in two 10,000-gallon ready-use tanks (each designed to give a ten-hour run)

is pumped by either of two electrically driven rotary pumps, through strainers and filters, and by a cross-connected system, up to the discharge valve at the end of the system, to which is connected the suction system of the turbine under test. Incorporated in the test house system are a steam-worked heater, two Titan centrifugal separators in parallel, a 1300-gallon overhead tank for centrifuged oil, and a second steam-worked heater, all of which can be by-passed when running on light oils. Additional by-pass arrangements are provided to enable turbines to be started up on light oil and switch over to heavy residual oil, hot oil circulating pipes being included. The system is, in brief, designed to supply up to 1000 gallons per hour of clean fuel at about 20 lb per square inch and at a suitable temperature to the suction side of the fuel pump of the engine being tested. Steam heating is provided to heat residual oils up to 120 deg. Fah. in the 10,000-gallon ready-use tanks, up to 180 deg. Fah. in the first heater for centrifuging, and up to 220 deg. Fah. in the second heater. Thermostatic control is provided on the heaters. Suitable filling arrangements are made to charge the ready-use tanks from a large tank farm. A "Tecalameter," read in conjunction with specific gravity readings taken from a sampling cock, measures the flow. Dip stick readings of the ready-use tanks are taken as a long-time check.

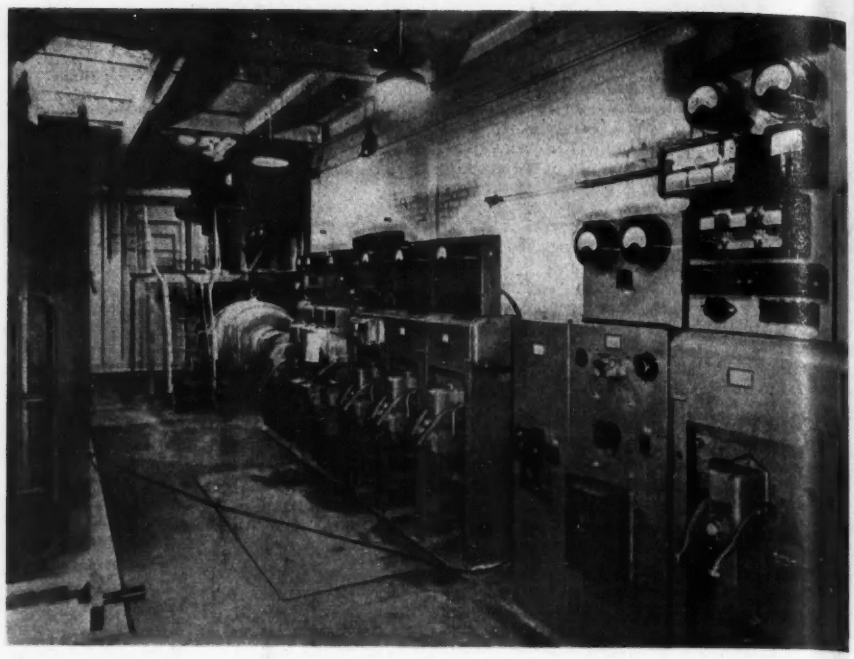


Fig. 4—Electrical Room

Lubricating Oil System

A complete lubricating system charged with "O.M.100" is provided by the standing plant, capable of supplying about 15,000 gallons per hour up to a pressure of 36 lb per square inch to the inlet of the distribution system of a gas turbine under test, and of receiving the drainage in a drain tank. In cases where the turbine has its ancillary supply pump, the oil can be supplied from a header giving a head up to about 16ft instead of through an electrically driven pump which gives the 36 lb per square inch referred to above, but the latter can be put into use at short notice if the turbine's pump (itself probably under test) were to fail.

The oil which returns to the drain tank is drawn out through a strainer by an electrically driven lobed booster pump which delivers it through "Clinsol" filters at about 30 lb per square inch to two water-cooled coolers and thence to the header tank, whence a downtake leads it, through a "Tecalameter" and orifice plate in parallel either direct or through the 36 lb per square inch pressure pump, also called the "through flow" pump, to the turbine under test. In order to maintain a constant level in the header tank, a preadjusted weir in the tank allows oil to overflow back to the drain tank, the booster pump being run at a speed to deliver more oil than the turbine requires. An Alfa-Laval centrifugal separator draws oil continuously from the drain tank and returns it there, or can similarly deal with the oil in the header tank.

To provide for a shut down due to grid failure (which would stop the booster pump) a small emergency pump supplied with electric power by an emergency diesel generator can lift enough oil from the drain tank to the header tank to keep the turbine bearings lubricated whilst the turbine is being turned by its turning motor (which, if direct current, can also be supplied from the emergency diesel generator). The 36 lb per square inch pressure pump can also be driven from this emergency diesel generator so as to keep up supply to the bearings (as long as the oil in the header tank will last) whilst the turbine is slowing down.

When the turbine under test is self-contained as regards its lubricating oil circuit, except for purifying, the centrifugal separator in the standing plant can be used through connections provided for flexible pipes. Temporary connections can be made to use the standing-plant coolers, if required, or to use the standing plant as a standby lubricating system.

A 5000-gallon storage tank provides the main reservoir from which the oil can be run down to the drain tank.

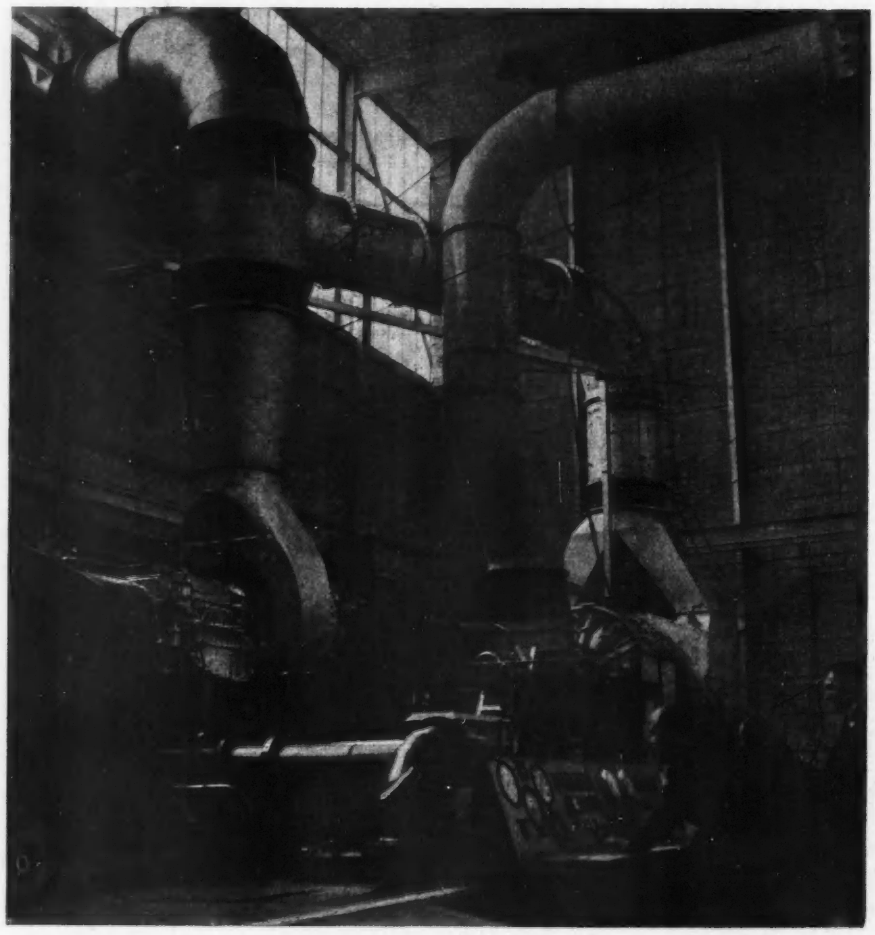


Fig. 3—End of Test Bay

Intercooler and Lubricating Oil Cooler Circuits

An 18in bore pipe from a pump which takes suction from a separate cooling tower forms a supply main, running along the east side of the test bed, to any intercoolers which may be part of the turbine under test. A similar return main is provided along the west side of the test bed and thence out of the building to a hot sump, whence it is pumped to the top of the cooling tower. Both supply and return mains are built up of interchangeable lengths to meet whatever positions the intercooler inlets and outlets may happen to occupy on the test bed. Control of pumps and key valves is arranged for from the control room. A 6in pipe is led off the end of the supply main to two lubricating oil coolers, which are in series, and thence direct to the hot

Fig. 5—Control Room

sump. The whole system is designed to circulate 230,000 gallons per hour and cool it from 89 deg. Fah. down to 72 deg. Fah. The nearby cooling tower for the Parsons 10MW gas turbine alternator is cross connected with the intercooler and dynamometer systems so that any tower can be used for any of the three services.

Electrical Equipment and Circuits

The main electrical supply is fed from the grid and distributed to neighbouring buildings at the usual 415V, three-phase, 50 c/s. This is, in general, used for driving the standing plant and for lighting the building, but a large portion of it can be converted into either 440V, three-phase, 60 c/s or 220V d.c., in order to run auxiliary machinery attached to gas turbine plants which are intended for ships having either of these systems. In addition, a 50kW supply of direct current at 220V is available from an emergency diesel-driven generator to give limited lighting, lubrication and other services needed to prevent damage to a turbine on trial, in case of failure of the main supply due to grid failure or other cause.

The main supply is led to a 750kW oil immersed switch on the 415V, 50 c/s three-phase switchboard in the electrical room (Fig. 4), and on this switchboard are mounted metalclad switches to supply the various services as follows: a 300kW motor alternator set for conversion to 440V, three-phase, 60 c/s; two 175kW transformer rectifier sets for conversion to 220V d.c.; three heaters in lubricating oil header tank; heater on lubricating oil centrifuge; overhead travelling crane in test bay; various pumps, &c., in the pump room, namely fuel oil boost pumps (two), lubricating oil boost pump, fuel oil separators with ancillary pumps, lubricating oil centrifuge, exhaust duct cooling water pump; workshop machinery; lighting (two circuits each single phase); welding points and small power plug points; two 30A switches in test bay for driving lubricating or other temporary pumps which may happen to come with turbines on test.

The motor alternator set mentioned above supplies current to the 440V, three-phase, 60 c/s switchboard (all in the electric room), where it is distributed to any of the following, which may be on the gas turbine under test: a starting motor (up to 300kW), turning motor (25kW), two fuel oil pressure pumps (each 25kW), two lubricating oil pumps (each 10kW), two miscellaneous pumps or fittings (each 25kW).

The two transformers and rectifiers supply a total of 350kW at 220V to the d.c. switchboard (which is fitted with open knife type switches), all in the electrical room, whence it is distributed to the same services as the 440V, three-phase, 60 c/s, and, in addition to the lubricating oil "through flow" pump, which is part of the standing plant in the pump room.

The emergency diesel generator is connected by a change-over switch to some of the items which are normally supplied by the transformers and rectifiers, namely: turning motor, one lubricating oil pump (on turbine), and lubricating oil "through flow" pump. It also supplies a small emergency pump to lift a limited flow of lubricating oil from the drain tank to the header tank and an emergency lighting circuit.

The emergency diesel generator is not intended to provide means to continue a trial during grid failure, but to provide means to supply sufficient lubricant whilst a gas turbine is slowing down after being shut off, and to turn it (and maintain an oil circulation) whilst it is subsequently cooling as is necessary for some types.

Oldham lamps, fitted with hold-off switches to close on main current failure, are wired into a 230V d.c. circuit throughout the building, as secondary lighting. A small amount of 24V d.c. lighting is provided (by separate transformers and rectifiers) for instruments in the control room. Workshop machines are fitted with 24V lighting (a.c.) from transformers.

Control and Instrumentation

In deciding upon the number and type of instruments which should be provided, it was necessary to consider the great variety of engines from small electrical generators to medium and large propulsion units which may be sent here for testing. Thus, in the first layout of the control room (Fig. 5) instrumentation by the well-known methods has been provided for complete performance analysis of gas turbo generators/alternators up to 1250kW and propulsion units up to 10,000 s.h.p. In doing this, however, some assumptions as to likely cycle arrangements have been inevitable, but in general the more complicated cycles thought likely have been catered for.

A propulsion unit with three-stage compression, two intercoolers, two reheat chambers, a free power turbine and heat exchanger can, for example, be tested.

Present commitments include tests on the performance and endurance running of the 1000kW gas turbine alternator, manufactured by W. H. Allen, Sons and Co., Ltd., of Bedford, and the acceptance trials of the reversible 10,000 h.p. dynamometer, manufactured by Heenan and Froude, Ltd., of Worcester, for which two Metropolitan-Vickers "Gatric" engines are coupled one at each end of the brake. All the necessary instrumentation for these two projects has been amply covered by the overall facilities available.

The instrument panels, of unit construction and interchangeable, were supplied finished with suitable "cut outs" ready for the flush mounting of the instruments. All the instruments, pressure gauge piping and electrical wiring, have been installed entirely by the test house staff. The Ministry of Works was responsible for the installation of the motorised valve and pump controls on the driving panel and the maker of the brake for the controls on its panel. Particular attention has been paid to the measurement of the mass flow through the air intake and to the means of obtaining the accurate temperature and pressure distribution throughout the whole of the aerodynamic cycle.

Fire-Fighting Equipment

Means are provided for the test house staff, which is small, to deal with small fires and also to take immediate steps to start fighting a major fire pending the arrival of the establishment fire brigade, which is a standing force.

Compaction of a Rock Fill Dam

We have received from the Institution of Hydraulics, the Royal Institute of Technology, Stockholm, Sweden, a booklet with the above title, which describes the methods used for the construction of a recent Swedish rock fill dam, namely, the Nissaström dam. The first part of this publication consists of a reprint of a paper submitted to the Fourth Congress on Large Dams by B. Hellström and L. Berg, and the second part is a summary of the discussion which took place at the Congress, which, it may be recalled, was held in New Delhi in 1951. Details are also given of the most recent measurements of the movements of the dam.

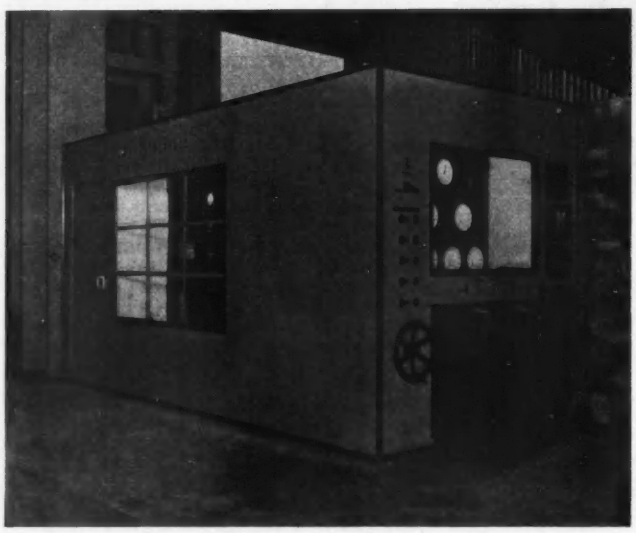
One of the disadvantages of the rock fill dam lies in the fact that appreciable settlement takes place after the rock fill is in position, so that considerable care must be exercised in the design and construction of the sealing membrane. One of the estimates given at the Congress for the settlement of such dams was about 2 per cent of the height, and it was suggested that the elimination of practically all settlement was an objective which would justify considerable extra costs. Nissaström dam was designed with the aim of reducing settlement as much as possible, and has proved very successful in this respect. The stone—tunnel spoil—was placed in horizontal layers about ½m in thickness, each layer being flushed with water, rolled, then vibrated with a compactor, and finally flushed again, thus reducing the thickness by about 17 per cent and the pore volume by about 30 per cent. The height of the dam is about 15m, which would have given a settlement of about 0·3m from the criterion given above. However, over a period of some fourteen months from the completion of the dam a slight upward movement was recorded at the crest, the lower part of the dam moving downwards. The movements were in all cases so small (the maximum rise was 8mm and the maximum settlement 12mm) as to be insignificant from a practical point of view, the rise at the crest being attributed to swelling as an after-effect of compaction.

Private Rocket Range.—A factory devoted exclusively to rockets and guided missiles is to be established by the Hawker Siddeley Group in Salisbury, a village near Adelaide, in South Australia, within reasonable distance of the Woomera Rocket Range. This station will be in effect a field trial centre in communication with Coventry, where basic research has been carried out since the war at the works of Armstrong Whitworth Aircraft, Ltd., under very heavy security. The launching ramps, electronic gear, calibration and other test equipment is already in process of installation. Commenting on this development, Mr. H. M. Woodhams, managing director of Armstrong Whitworth Aircraft, Ltd., stated that it was a pity, in some ways, that the public must for security reasons remain unaware of the immense facilities placed by the Australian Government at the disposal of the Commonwealth rocket project. The British Government, too, he stated, had poured time, money and effort into securing for Britain and the Commonwealth a lead in this new science. He maintained that in certain respects the work was a constant race against time, and that research indicated that we were on the threshold of great developments which were once thought fantastic.

Automatic Control of Open-Hearth Furnaces

A comprehensive scheme has been devised for the automatic control of eight open-hearth furnaces in the new melting shop of John Summers and Sons, Ltd., at Shotton. In particular provision is made for controlling the maximum roof temperature and the furnace pressure and for automatic reversal of the furnace by operation of a reversal switch. The indicating, recording and control equipment for each furnace is housed in a Tinsley control cubicle which is pressurised to keep out the dust-laden steelworks atmosphere.

A RECENT visit to the Shotton steelworks of John Summers and Sons, Ltd., gave us the opportunity of seeing the automatic control system which has been installed for the eight Salem open-hearth fixed furnaces in the new melting shop. Each of these furnaces is of 150 tons capacity, is designed for mixed fuel firing by fuel oil and coke oven gas, and each is equipped with a separate pressurised control cubicle. The cubicle incorporates an operator's panel carrying indicating instruments above the operator's desk, as shown on the right of our first illustration. On the furnace side of the cubicle there is a recorder panel. It will be seen that the indicator and recorder panels are visible through separate windows in the pressurised control cubicle and that the operator standing at his desk has the furnace on his left. Finally, the cubicle accommodates the various automatic controllers which can be seen in the accompanying interior views of the equipment.



Furnace Control Cubicle

Instrumentation and automatic control are applied extensively in the operation of these furnaces. Briefly, the following functions are exercised automatically. First, maximum heat input is maintained during the charging period and thereafter the heat input is based on maximum roof temperature, as described below. Secondly, in association with this function, control is maintained of the oil/steam ratios the oil/gas ratio and the fuel/air ratio. Thirdly, furnace pressure is maintained at the centre of the roof crown. Fourthly, the furnace is reversed automatically when the operator throws a reversal switch mounted near the desk.

Maximum Controller

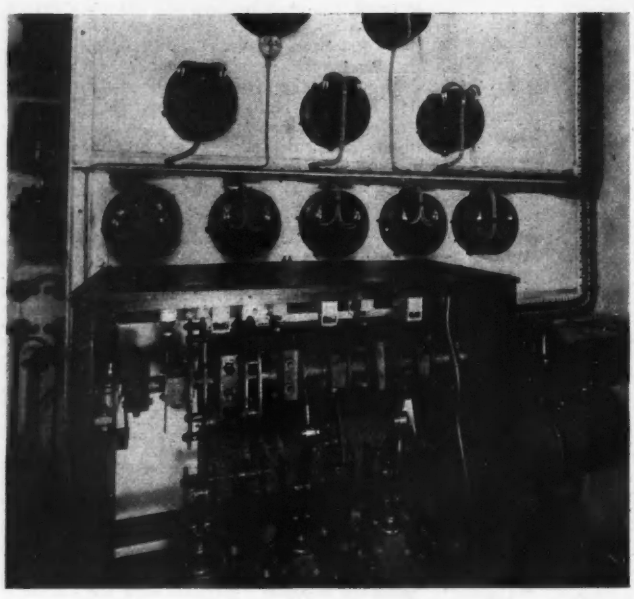
As mentioned above, the maximum controller has a dual function. During the charging period, when the roof temperature is low, this controller maintains the heat input at a preset maximum value. Towards the end of the charging period and during the refining period when the roof temperature approaches the control point, the maximum controller limits the maximum roof temperature to the desired value. The changeover from maximum heat input control to maximum roof temperature control is completely automatic.

The roof temperature of the furnace is measured by three partial radiation pyrometers, which are sighted on three points on the furnace roof through holes in the back wall. The temperatures measured by the pyrometers are indicated and recorded on the instrument panels and the maximum of these three temperature signals is selected continuously and automatically and used to actuate the maximum controller, as described more fully below. A changeover valve is included in the oil circuit from this controller and by means of this valve the controller can be used to operate either the fuel oil valve or the coke oven gas valve. It is thus possible to use the maximum controller to maintain the heat input and roof temperature either by controlling the oil flow to the furnace (with a gas flow maintained at a preset ratio to the oil flow by means of the oil/gas ratio controllers, described later) or by controlling the gas flow only. In the latter eventuality a constant amount of oil can be provided by setting the oil valve at the required position remotely by hand.

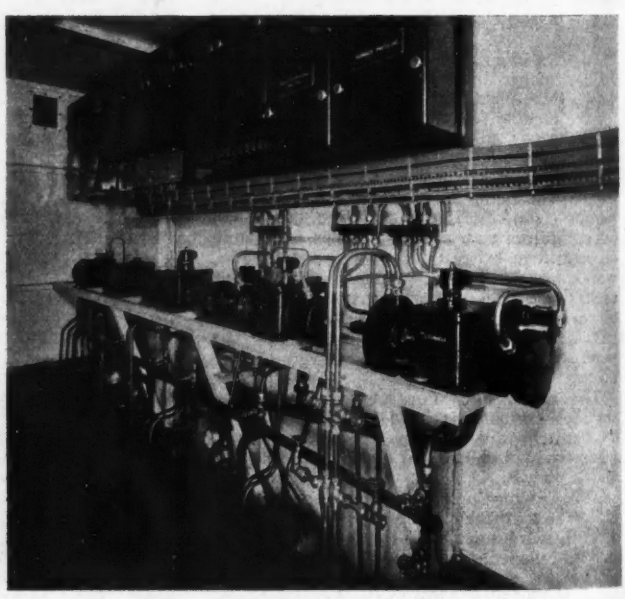
Provision is also made on this controller to close the oil valve during the reversal cycle. During the reversal cycle there is a certain finite period when the oil is off to both ends of the furnace and in this period the oil control valve is made to close at a certain rate, remain closed for a certain time and then to open at a certain controlled rate. The opening and closing rates of the valve, together with the time during which the valve is closed, are adjusted so that the oil control valve is in the correct position, when oil is put on to the new end of the furnace, to give a rapid return to the control point without exceeding it.

Selection of the maximum temperature signal which determines the operation of the maximum controller, as mentioned above, is carried out by a "maximum channel selector." This selector is supplied with five signals, three from the roof temperature amplifiers, one from the oil flow transmitter and one from the gas flow transmitter.

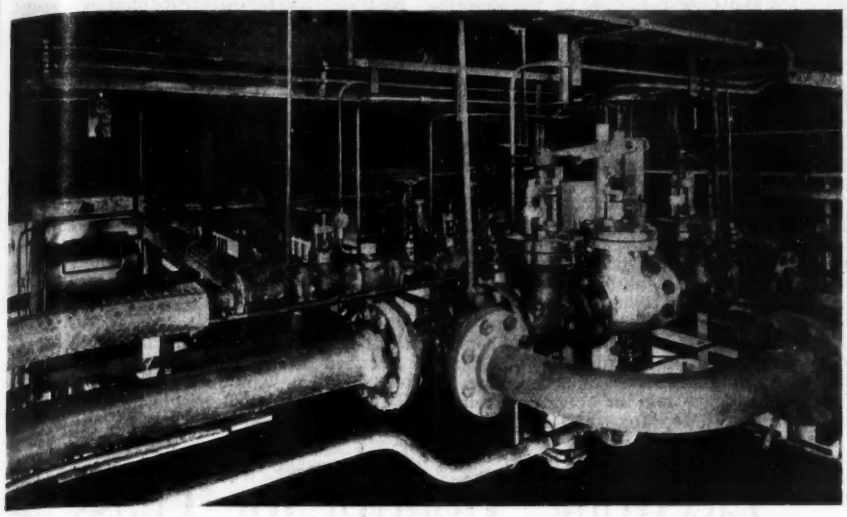
These signals, which vary from 0mA to 30mA, are applied to potentiometers, the tapping points of which are moved to adjust the control points. For the roof temperature setting a triple-ganged potentiometer is used to adjust the control point on the three roof temperature equipments at the same time, while separately calibrated potentiometers are used for maximum gas and oil flows.



Automatic Reversal Unit with Covers Removed



Automatic Controllers



Valve Platform

These settings are adjusted so that at the control point the potential of each input to the maximum selector will reach 40V. These voltages are applied to one capacitor, each through a separate diode rectifier. The charge on the capacitor, therefore, depends on the maximum signal, which is amplified and applied to the controller. By this means the controller will keep the fuel flow at such a level that the maximum temperature of the roof does not exceed the set value or that the gas or oil flow will not exceed a preset maximum value.

Fuel, Steam and Air Controllers

Oil/Steam Ratio Controller.—Steam flow to the furnace is regulated by a controller to maintain the desired oil flow/steam flow ratio. Differential pressures obtained from orifice plates in the oil and steam mains are applied to diaphragm units on the controller which operates a control valve in the steam main. This controller is fitted with a zero setting unit to give a variable flow ratio over the flow range; the ratio is altered to give a larger proportion of steam as the oil flow is reduced and in this way the velocity at the burner is maintained to obtain efficient atomising. The settings for the oil/steam ratio and for the zero of this controller are brought out to panel settings which are mounted adjacent to the furnace operator's desk. The steam/oil ratio can be varied between 3·5 lb and 12 lb per gallon.

Oil/Gas Ratio Controller.—The oil and coke-oven gas flows are metered, using orifice plates in the fuel mains, and the differential pressures obtained from these orifice plates are applied to the oil/gas ratio controller which maintains the required oil flow/gas flow ratio. The controller is fitted with a zero setting unit and with panel settings for oil/gas ratio and gas zero. As mentioned earlier, this controller is used when the maximum controller adjusts the oil flow to the furnace. When the change-over valve in the maximum controller circuit is put into the "gas" position, the oil/gas ratio controller is switched off.

Fuel/Air Ratio Controller.—The flow signals for oil and gas are summated electrically and this summated signal, together with an electric signal proportional to the air flow is passed to electric input units on the fuel/air ratio controller. This controller operates vanes at the exit of the air fan to maintain the combustion air flow to the furnace in the required ratio to the total fuel flow. The controller is also fitted with a zero setting unit and with panel settings for fuel/air ratio and air zero.

Furnace Pressure Controller

The furnace pressure is measured at the centre of the roof crown by a null-balance pressure detector and the output of this detector, which is an electric current, is indicated on the indicator panel and recorded on the recorder panel. The furnace pressure signal is also transmitted to the furnace pressure controller which controls the pressure by positioning a louvre damper at the outlet of the waste heat boiler fan and by controlling the speed of the fan. The louvre damper works from the fully open to the half-open position and the waste heat boiler fan speed is adjusted so that the required furnace pressure can be obtained when the louvre damper is set in some position in this range. This form of control produces a saving of the power consumed by the waste heat boiler fan as it prevents excessive throttling of the flow at the fan outlet. A panel setting for adjusting the furnace pressure control point is also provided.

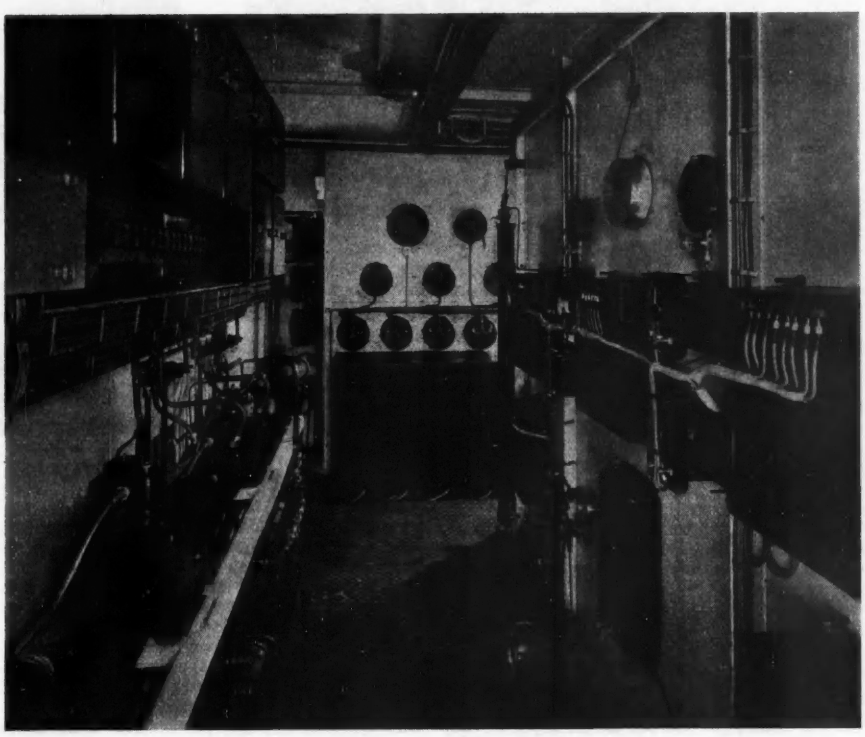
Each of the eight waste heat boiler fans is driven by a 100/28 h.p., 890/580 r.p.m. totally enclosed, fan-cooled "NS" variable-speed, a.c. motor made by Laurence Scott and Electromotors, Ltd. The motors are arranged for stepless speed variation between the specified limits, by variable voltage control from induction regulators in which the moving part is electrically linked to the automatic control mechanism operating the louvre damper.

Automatic Reversal Unit

When the furnace operator throws the reversal switch mounted near the control desk, the furnace is reversed automatically by the automatic reversal unit. This action initiates the reversal cycle whereby the oil, steam, air, waste gas and coke-oven gas reversal valves are operated in the correct sequence. The reversal unit, which is accommodated in the control cubicle, consists of a motor driving a horizontal shaft carrying a series of cams specially cut to give the correct timing sequence for the reversal. They operate hydraulic pilot valves which in turn operate hydraulic cylinders coupled to the reversal valves for oil, steam and coke-oven gas. The air and waste gas are reversed by an electric drive motor which is started by limit switches operated by cams in the reversal unit. The reversal drive motor is stopped at the end of the reversal valve travel by a limit switch on the rope linkage between motor and reversal valves. The electric circuit for the automatic reversal unit is interlocked so that once the cycle has been initiated by throwing the reversal switch, it will be completed in the correct sequence even if the switch is thrown back to the original position during the reversal cycle. Thus, the reversal cycle cannot stop in mid position. Should the reversal motor fail, a handwheel is provided so that the furnace operator can turn the camshaft by hand.

A typical sequence for reversal would be as follows, with the approximate times after operation of the reversal switch:—(1) Coke-oven gas off at No. 1 end (three and a half seconds); (2) oil off at No. 1 end (five seconds); (3) air and waste gas change-over begins (six seconds); (4) steam off and trace steam on at No. 1 end (seven and a half seconds); (5) steam on and trace steam off at No. 2 (eight seconds); (6) air and waste gas change-over completed (thirteen seconds); (7) oil on at No. 2 end (fifteen seconds); (8) coke-oven gas on No. 2 end (twenty-three seconds). The coke-oven gas, oil and steam valves are quick acting, but the air and waste gas reversal valves are motor driven, and the change-over from one end to the other takes approximately seven seconds. The steam reversal valves are mechanically linked with their corresponding trace steam reversal valves and are operated together.

One of our illustrations shows the automatic



Interior of Control Cubicle

cam-operated reversal unit with the covers removed ; above it is the back of the indicator panel. Another illustration shows the controllers ; they are, from left to right, the maximum controller, the furnace pressure controller, the total fuel/air ratio controller, the oil/steam ratio controller, and the oil gas ratio controller.

All the controllers are Tinsley/Askania vertical jet-pipe controllers, and are operated by oil pressure, the oil being supplied by a double helical gear pump, with a standby oil pump. On failure of the main pump the control oil pressure would fall slowly and the standby pump would be started automatically. The hydraulic circuits for the automatic reversal unit are supplied by a separate system and again a standby pump is provided which starts automatically on failure of the main pump. Warning lights are provided on the control desk to indicate to the furnace operator the availability of control oil or reversal oil.

The oil, steam, gas and air flows are measured by flow meter transmitters which are mounted on the valve platform below stage level. The values of these flows are transmitted electrically to the control cubicle to operate flow indicators, recorders and integrators.

Protective Arrangements

Equipment is included in the cubicle to safeguard the plant in the following emergencies : failure of three-phase power supply ; failure of single-phase power supply ; failure of oil pressure.

Under these conditions a magnetic valve in the fuel oil line closes and cuts off the fuel oil to the furnace, while the coke-oven gas valve is locked in its last working position. The coke-oven gas valve is not arranged to close under emergency conditions as this would mean that the demand for coke-oven gas for the whole melting shop would be cut off quickly and consequently the load would be thrown back on to the coke-oven plant. Provisions are made to enable the furnace operator to take manual control of the oil and gas flows to the furnace.

Indicating and Recording Panels

Standing at his control desk the operator can see the furnace on his left and the indicators in front of him, and can conveniently operate all the controls required for running the furnace. The operator's panel accommodates indicators for oil, steam, gas and air flows, together with an indicator which shows the total heat flow to the furnace on mixed firing. On this panel there are also three indicators for the temperatures at three points on the furnace crown.

Below the indicator panel window is the operator's desk with the hand-control valves, which are used for switching the various circuits from automatic to hand control and for operating the various control organs remotely by hand. Two gauges, showing the oil and steam pressures in the mains to the burners, are also mounted on this desk.

On the left of the window are mounted the push buttons to raise and lower the furnace doors, and above them the switch to initiate the reversal cycle. On the right of the window there are three boxes fitted with hinged lids. The top box houses a series of switches for checking the various measuring circuits, the second box contains the setting knob for the roof temperature control point, the third the setting knobs for the control point for maximum oil flow and maximum gas flow, and the bottom box carries the setting knobs for the various ratio controllers and for the furnace pressure controller.

The side of the cubicle facing the furnace houses an instrument panel carrying all the recorders. Normally, these instruments are not used by the operator for running the furnace, but by the management and technical staff.

On this panel there are three "Triplex" recorders : one for oil, steam and gas flows ; one for the temperatures at the three points on the furnace crown, and one for furnace pressure and air flow, the third recorder element in this unit being a spare. There is also a recorder for oil and steam temperatures, another for chequer temperatures, and a third for liquid steel temperature. Finally, the panel accommodates a clock and separate integrators for oil, steam gas and air.

The instrumentation and automatic control described in this article was designed, in collaboration with John Summers and Sons, Ltd., by Tinsley (Industrial Instruments) Limited, who manufactured the equipment.

Electronic Control for Glass Grinding Machines

THE operation of automatically grinding the edges of car windows at the St. Helens works of Triplex (Northern), Ltd., involves accurate control of a variable-speed drive for the glass grinding machines. Because the speed variation required is wide and the changes are rapid, the company has adopted an electronic system in place of the mechanical equipment hitherto used for speed control. The new control gear described below was developed and made by the General Electric Company, Ltd.

As shown in the photographs reproduced herewith (Figs. 1 and 2), the windows are mounted in pairs on a rotating chuck and are held in position by means of toggle action clamps. The grindstone, which rotates at constant speed in bearings mounted on one end of a pivoted arm, is held in contact with the edge of the glass by counterweights. The speed at which the glass passes over the stone is critical and the chuck speed must therefore be accurately controlled so that the windows shall be ground to the correct profile. A considerable speed range is involved and at certain points, particularly when sharp corners are being ground, a very rapid variation of the chuck speed is necessary.

The chuck is driven by a 1 h.p. variable-speed d.c. motor. As can be seen from the simplified diagram (Fig. 3) this machine is separately excited from a bridge-connected metal rectifier which is fed from the secondary of a transformer T_3. The armature supply is derived from a pair of thyratrons V_1 and V_2. Control of the armature current and, therefore, of the motor speed, is effected by comparing a fixed proportion of the output voltage of the thyratrons with a reference voltage proportional to the required motor speed. The resulting "difference" voltage is fed to an electronic amplifier whose output controls the operation of a phase-shifting network in the grid circuit of the thyratrons in such a way as to increase or reduce the speed of the motor to the required value.

The reference voltage is obtained from a small potentiometer which is supplied from a stabilised d.c. source. The setting of this potentiometer is varied by means of a cam mounted at one end of the machine (Fig. 1), and rotating in synchronism with the chuck. The cam profile, which, of course, varies according to the size and shape of the windows being ground, is determined empirically, and the motion of the follower

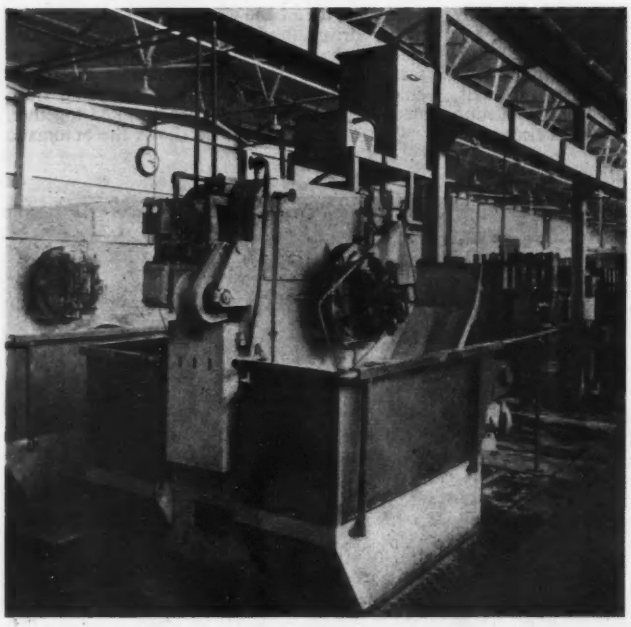


Fig. 1—Electronically Controlled Machine for Grinding Edges of Car Windows

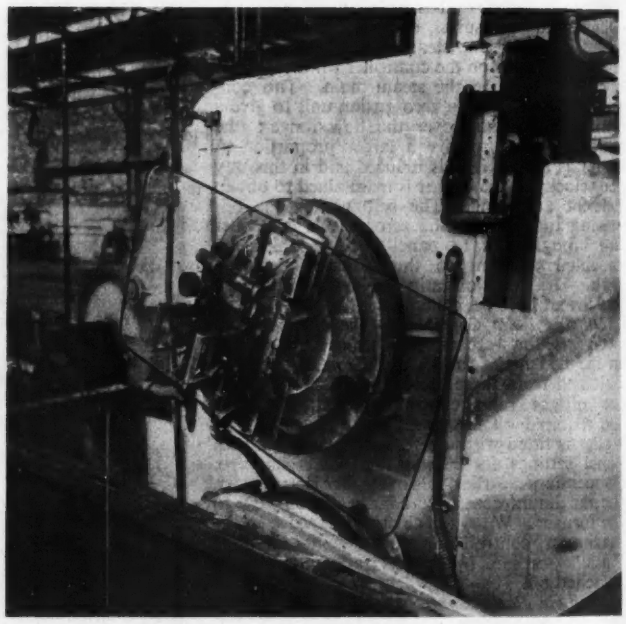


Fig. 2—Rotating Clutch and Glass Clamping Arrangements

is transmitted to the potentiometer slider through a link mechanism. The voltage with which the output from the potentiometer is compared is that across the resistor R_2, which forms one arm of the potentiometer R_2–R_3 connected across the output terminals of the thyratrons.

The way in which the phase-shifting network operates to vary the output of the thyratrons may be understood by considering, first, a simple circuit consisting of a pure resistor R and a pure reactor X connected in series and supplied, at a voltage E_S, from the secondary winding of a transformer (Fig. 4(*a*)). If the voltages across R and X are represented by vectors E_R and E_X respectively (Fig. 4(*b*)), then the supply voltage

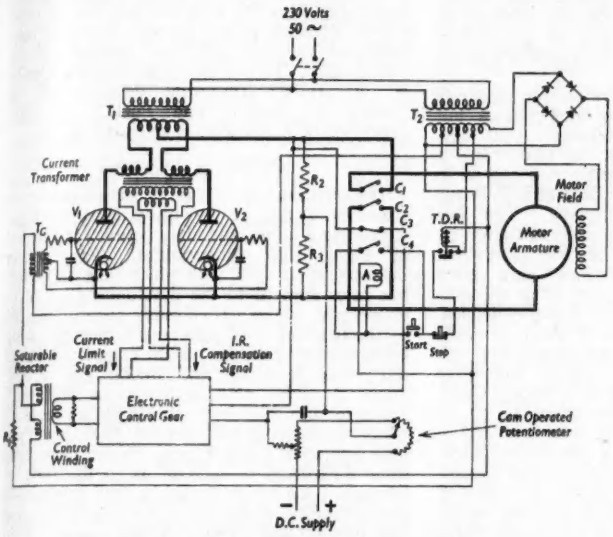


Fig. 3—Simplified Diagram of Control Circuit

will be represented by the resultant vector E_S. The vectors E_R and E_X will be at right angles to each other whatever the relative values of R and X may be. Therefore, for varying values of these components, the locus of the point at which the vector E_R meets the vector E_X will be a semi-circle with the vector E_S as diameter, if the supply voltage remains constant.

If connections are now taken from the centre point of the transformer secondary and from the connection between R and X as shown in Fig. 4(*c*), the voltage V between these leads is represented by a vector drawn from the centre point of the vector E_S to the point of junction of vectors E_R and E_X (Fig. 4(*d*)). It will be seen that this vector is the radius of the semi-circle of which the vector E_S is a diameter and, as a result, if the relative values of R and X are varied, the vector V, while remaining of constant length, will rotate about the mid-point of the vector E_S. Thus, if either of the components R and X is variable, it is possible to obtain an output of constant voltage equal to $E_S/2$ whose phase relationship with the supply voltage is variable.

In the control circuit shown in Fig. 3, the series components of the phase-shifting network are a fixed resistor R_1, and a saturable reactor, while the supply is obtained from tappings on the secondary winding of transformer T_2. The control winding of the saturable reactor is fed with the amplified "difference" voltage obtained from the control circuit so that any variation in this "difference" voltage produces a corresponding variation in the inductance of the reactor. The resulting constant-voltage, variable-phase output from the phase-shifting network is supplied to the primary winding of grid transformer T_G. One end of the secondary winding of T_G is connected to the grid of thyratron V_1 and the other end to the grid of V_2, the centre point of the winding being connected to the common cathode lead. Thus, the grid voltages of the two thyratrons are 180 deg. out of phase as required for full-wave rectification. Since the supply to the anodes of the thyratrons is in phase with the supply to the phase-shifting network, it will be clear that any variation in the "difference" voltage obtained from the control circuit will produce a proportional variation in the phase difference between the grid and anode voltages of the thyratrons. This, in turn, will result in a variation of the firing period of the thyratrons which will vary the armature current. Thus, any movement of the cam follower will result in a proportional variation of the motor speed, and the grinding speed at all stages of the operation will be automatically determined by the cam profile.

To start the machine, the main switch is first closed to connect the primary windings of transformers T_1 and T_2 to the 230V, 50 c/s supply. The motor field is immediately energised from the secondary of transformer T_2, which also supplies the heaters of the thyratrons and the power pack for the electronic control gear and reference potentiometer. At the same time, the operating coil of time delay relay *TDR* is energised and, after allowing an adequate time for the thyratrons to warm up, the relay closes. The motor can now be started by means of the "start" push button. Pressure of this button completes the circuit through coil A, which causes its associated contactors to operate. The contactors C_1 and C_2 connect the motor armature to the output from the thyratrons while the contactor C_4 closes to maintain the circuit through coil A. The remaining contactor, C_3, which opens at the same time as the other contactors close, controls the operation of the electronic gear in such a way that the load is applied gradually to the thyratrons.

Two auxiliary control circuits are also provided; they are energised from a current transformer in the anode circuit of the thyratrons. One circuit is designed to limit the armature current to a predetermined safe value in order to

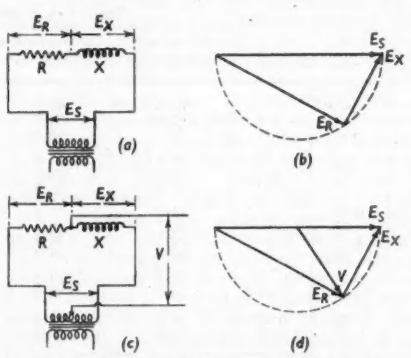


Fig. 4—Principle of Phase Shifting Network

avoid overloading of the thyratrons, while the other provides compensation for the natural drop in speed of the motor at increasing mechanical loads.

Each d.c. motor drives two chucks, one on each side of the machine, so that four windows may be ground simultaneously. The reference potentiometer is mounted alongside the motor, while the rest of the control gear, including the thyratrons, is housed in a sheet steel cubicle, which, together with the main transformer, is supported on a platform above the motor.

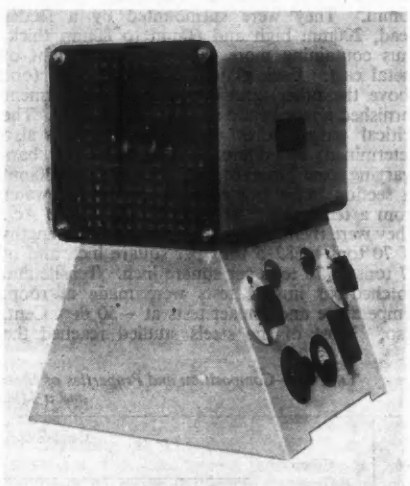
THROUGHPUT OF OIL REFINERIES.—The Anglo-Iranian Oil Company, Ltd., states that the provisional throughput totals for 1952 for the Llandarcy, Grangemouth and Pumpherston refineries were 4,254,000 tons, 2,375,000 tons and 159,000 tons respectively, with an overall total of 6,788,000 tons, which is approximately 1,500,000 tons more than in 1951.

A High-Temperature Tube Furnace

OUR illustration shows a tube muffle designed to operate at temperatures up to 1400 deg. Cent. and, therefore, to be suitable for the analytical determination of high alloy steels. It is made by Wild-Barfield Electric Furnaces, Ltd., Watford, Herts.

The new furnace is a self-contained equipment with built-in hand temperature control and pilot lights. It is designed to take two standard combustion tubes of 1⅜in outside diameter. The heating chamber is 4in square and has a 6in heated length with well-insulated vestibules at each end to give the optimum uniformity of temperature. The heating chamber itself is surrounded by powder insulation contained in the steel casing and at each end there is a blue asbestos plate through which the elements protrude. It is claimed that, over a length of 4in (which is ample for normal sulphur and carbon determinations) temperature uniformity is obtained to within ±10 deg. Cent. at 1390 deg. Cent. At each end of the furnace, beyond the insulated vestibule, there is a ventilated compartment housing the connections to the heating elements. The combustion tubes are not supplied with the furnace and it is recommended that the tubes should be 24in long to ensure that the ends are adequately spaced from the furnace itself.

Whereas muffles for use up to 1050 deg. Cent. are usually fitted with nickel-chromium resistance



High-Temperature Tube Furnace

elements and an energy regulator, such as a "Simmerstat," the muffles for 1300 deg. to 1390 deg. Cent. described here embody elements of silicon carbide, which require rather more elaborate control arrangements. Because of its composition the resistance of a silicon carbide element changes with age. To compensate for this effect there is an ageing control switch, seen on the left-hand side of the plinth, which provides a means of rearranging the series/parallel connecnections to the heating elements. The switch on the opposite side controls the ballast resistance which is connected permanently in series with the element network and provides additional intermediate compensation between the steps of the ageing control switch.

A contactor unit is provided to make and break the main electricity supply, the control circuit of the contactor being fed through the energy regulator. This regulator provides a means of adjusting the energy input and thus controls the furnace temperature, whilst interlocked with the contactor there is a solenoid-operated circuit breaker which safeguards the system against accidental overloading in the event of the ageing control switch being incorrectly set. A moving-coil rectifier ammeter, with its associated current transformer, measures the current taken by the elements.

The furnace, rated at 1·75kW, is suitable for operation on 200/250V a.c. supplies, and is supplied ready for installation with a 6ft length of three-core cable.

Metallurgical Topics

High-Strength Steel Castings

HIGH-GRADE steel castings have, of late years, been used in components for which castings would formerly have been unacceptable. When designs are governed by a need for reduction of weight to a minimum, high stresses are involved and the castings must therefore possess high strength with adequate ductility and toughness—properties which may be attained if a suitable choice is made of composition and treatment. The influence of alloy elements in forgings or rolled bar is well known, but the question remains as to how far the same influences may be utilised in castings. An investigation has been undertaken by H. Juretzek, A. Krisch and W. Trommer* with the object of studying the effect of alloy additions in high-strength steel castings.

In order to carry out a general survey of compositions appropriate for high-strength castings, 283 melts were prepared in a 20kg h.f. furnace. The compositions were chosen to represent a cross section of steels containing one, two, three or four alloy elements. The steel was cast in a sand mould into test plates having the following dimensions:—Length, 250mm; vertical height, 125mm; and thickness (tapered), 20mm to 30mm. They were surmounted by a feeder head, 200mm high and 60mm to 80mm thick, thus containing more than half the weight of metal cast. Each plate yielded four bars (one above the other) and each bar after treatment furnished a tensile and an impact test piece. The critical temperatures of each steel were also determined by dilatometer tests. The bars (varying from 20mm by 20mm to 20mm by 30mm in section) were treated by quenching in water from a temperature at least 30 deg. above Ac_3. They were then tempered to give tensile strengths of 70 tons to 82·5 tons per square inch and of 57 tons to 70 tons per square inch. Tensile and notched-bar impact tests were made at room temperature and impact tests at −50 deg. Cent. also. Most of the steels studied reached the tensile strength of 70 tons per square inch, or would have done so with a slight change in heat-treatment, and gave at the same time a yield ratio (ratio of 0·2 per cent yield strength to tensile strength) of 80 per cent. Elongation and reduction of area were considered little adapted to the estimation of capacity for plastic deformation; on the other hand, the notched-bar impact value was held to be most significant in this connection. It was found that the most favourable impact values at the hardness levels investigated were, in general, obtained in steels containing molybdenum. This need not be higher than 0·3 per cent. Additions of chromium, manganese and nickel have also given favourable results, but larger amounts than 1 per cent chromium, 1·4 per cent manganese or 2 per cent nickel are not recommended, as they were found to lead rather to a fall in toughness for the same tensile strength. A vanadium addition was not so favourable as a molybdenum addition, whilst copper in amounts exceeding 0·5 to 1·0 per cent was shown to be harmful. Multi-alloy steels, with few exceptions, showed no advantage over corresponding steels with a single alloy element. Multi-alloy steels are accordingly stated to be justified only if they cannot be dispensed with on the grounds of securing adequate strength, e.g. on account of improved depth-hardening or superior casting characteristics.

The impact value in the low-temperature tests was always less than at room temperatures, but the extent of the fall between +20 deg. and −50 deg. Cent. varied. In some cases it amounted to 20 or 30 per cent; in others to 70 per cent or more and a characteristic brittle fracture was frequently observed. The best low-temperature values were often not given by the steels which showed the best results at room temperature; conditions which gave good impact values at −50 deg. Cent. within the individual alloy groups could not be closely defined. There were only three melts in which a tensile strength of over 63·5 tons per square inch was accompanied by an impact value of more than 5 mkg per square centimetre at −50 deg. Cent., obtained with the DVM test piece 10mm by 10mm by 55mm with a notch 3mm deep and of radius 1mm.† These were a chromium-molybdenum, a manganese-molybdenum and a manganese-vanadium steel, as shown in Table I. For a strength of 57 tons to 63 tons per square inch, this value was reached in twenty-two melts, including three chromium-molybdenum, four chromium-nickel-molybdenum, three chromium-molybdenum-vanadium, and two chromium-nickel-molybdenum-vanadium steels (Table I). A further eight of these steels were also alloyed with molybdenum, so that only two molybdenum-free steels were found in this group.

On the whole, chromium-molybdenum steels, with or without further additions, showed the best prospects of reaching a good low-temperature impact figure at the level of tensile strength investigated. The addition of 0·5 per cent of nickel to steel with 1 per cent chromium and 0·2 to 0·4 per cent molybdenum brought no further improvement on the good value shown by the chromium-molybdenum steel, whilst reversal of the nickel and chromium contents gave somewhat higher strength and lower impact value. This alloy group (chromium-nickel-molybdenum) has been the subject of exhaustive investigation (with results which in general agree with those here reported) and is used in Britain and in the U.S.A. for high-strength castings.

In this report, which deals only with small sand castings, water-quenched and tempered, six pages of closely printed experimental results are supplemented by about fifty references to other papers on alloy steel castings.

TABLE I.—*Composition and Properties of Steels with a Tensile Strength* (a) *Over 63·5 Tons Per Square Inch*, (b) *Between 57 and 63 Tons Per Square Inch and a Minimum Impact Figure of 5 Mkg Per Square Centimetre at −50 Deg. Cent.*

No.	Group	Composition, per cent						Tensile tests at room temperature				Notched-bar impact tests (DVM specimens), mkg per sq cm	
		C	Mn	Cr	Mo	Ni	V	0·2 per cent yield strength, tons per sq in	Tensile strength, tons per sq in	Elongation, per cent, l = 5d	Reduction of area, per cent	At 20 deg. Cent.	At −50 deg. Cent.
	(a)												
32	Cr-Mo	0·23	0·72	0·60	0·85	—	—	65·6	69·2	12·3	39	9·0	5·6
71	Mn-Mo	0·28	1·32	—	0·44	—	—	69·9	74·3	10·1	28	6·0	5·1
74	Mn-V	0·23	1·46	—	—	—	0·10	59·2	64·5	13·3	58	8·8	5·0
	(b)												
32	Cr-Mo	0·24	0·78	0·67	0·42	—	—	51·0	57·4	16·4	43	8·3	7·8
33	Cr-Mo	0·23	0·72	0·60	0·85	—	—	54·3	59·4	15·2	36	8·8	6·2
35	Cr-Mo	0·27	0·86	1·39	0·22	—	—	52·6	59·4	13·9	48	9·4	5·7
183	Cr-Ni-Mo... ...	0·25	0·56	0·95	0·23	0·62	—	51·3	58·4	15·2	45	10·5	7·7
184	Cr-Ni-Mo... ...	0·27	0·54	0·96	0·52	0·47	—	54·7	60·8	8·8	21	9·1	7·1
186	Cr-Ni-Mo... ...	0·26	0·53	0·63	0·23	1·10	—	52·5	58·4	13·6	35	8·5	6·8
187	Cr-Ni-Mo... ...	0·29	0·69	0·60	0·39	1·08	—	51·7	58·9	13·6	29	7·8	6·7
205	Cr-Mo-V[1] ...	0·21	0·73	1·01	0·27	—	0·12	53·1	57·5	13·3	45	10·8	5·6
206	Cr-Mo-V[1] ...	0·29	0·53	1·42	0·26	—	0·13	54·5	60·0	8·8	16[2]	10·0	5·9
275	Cr-Ni-Mo-V ...	0·23	0·60	0·99	0·21	0·63	0·19	59·1	61·6	13·9	39	9·7	7·6
276	Cr-Ni-Mo-V ...	0·26	0·74	0·54	0·24	0·95	0·09	54·2	59·4	11·9	24[2]	8·9	5·7

[1] The text gave three in this group but the tensile strength of the third was only 51·8 tons per square inch.

[2] Casting defect in test piece.

Materials for Gas Turbines

A PROGRESS report, consisting of a series of papers on various aspects of gas turbine development, was communicated to a meeting of the American Society of Mechanical Engineers on September 8 to 11, 1952, by the Gas Turbine Power Division of the Society, and has been published in the February number of its *Transactions*. Part of the report was a paper by A. A. Hafer* reviewing developments in "Materials, Cooling and Fuels." A brief indication of its contents is given below.

MATERIALS: ALLOYS

The obvious way of raising gas turbine cycle efficiency would be by using superior high-temperature alloys and thus permitting the use of higher inlet temperatures. The greater intensity, since 1940, with which time and effort has been devoted to the development of high-temperature alloys has certainly been influenced by the desirability of obtaining higher operating temperatures in the gas turbine engine. A list of thirty-nine American and British gas turbine alloys is given, with compositions and with 100-hour and 1000-hour stress-rupture tests at temperatures from 1200 deg. to 1800 deg. Fah. (660 deg. to 982 deg. Cent.). There have been some differences of opinion as to the type of laboratory test which should be used to evaluate the suitability of the alloy for highly stressed high-temperature parts. Creep tests, often supplemented by observations of structural changes during creep, have commonly been employed to determine life under given conditions. Other work has indicated that the effect of creep predominates above a certain temperature and fatigue is more important below that temperature. A combined stress test, in which both fluctuating and steady stresses are involved, has been proposed to evaluate both conditions. In a series of wheel-bursting tests, carried out by General Electric, it was concluded that the most important factor contributing to high and consistent bursting speed was ductility.

The development of new high-temperature alloys has resulted in new and more complex production procedures; for example, in methods of machining materials having difficult machining properties. Production of components with a high degree of finish, and to closer tolerances than usual, was a gas turbine requirement which has not only led to developments in machining technique, but has also resulted in new advancements in precision casting. In addition to the use of this method for cast turbine blades, it now seems feasible to cast small axial turbine discs; and the U.S. Navy solar model gas

* "Influence of Alloy Constituents on the Mechanical Properties of Heat-Treated Steel Castings" *Archiv Eisenhüttenwesen*, January/February, 1953, Vol. 24, page 69.

† In the absence of a direct comparison the equivalent Izod figure cannot be given, but it is probably about 200-lb.

* *Trans. A.S.M.E.*, February, 1953, page 127.

turbine engine, driving a water pump, is being produced with a radial turbine rotor cast by the "lost wax" process. Each of these metallurgical advances helps to make the gas turbine more competitive with other forms of prime movers.

Many high-temperature alloys contain large percentages of "strategic" materials, but some of the new "austerity" compositions appear to have properties which are as good as, if not better than, those of the alloys which they replaced. There is some opinion in favour of ferritic steels for gas turbine engine rotors. The ferritic steels have many advantages over the austenitic type of steel; they are cheaper, contain less "strategic" material, are more easily welded, respond to heat-treatment, have a lower coefficient of expansion, and a higher heat conductivity, are easier to produce especially in large sound forgings, and are less prone to vanadium attack.

The probable present-day practical temperature limit for alloys is estimated to be 1500 deg. to 1600 deg. Fah. (815 deg. to 870 deg. Cent.), but perfection of the molybdenum-base and chromium-base alloys offers some hope of raising this limit to 1700 deg. Fah. (926 deg. Cent.).

Ceramics and Ceramals

Their high melting point, low density and potentially low cost make ceramics an attractive material for gas turbine engine hot parts, but up to the present brittleness and inability to withstand thermal shock have prevented their extensive use. The real value of ceramics now appears to be in the form of an extremely thin coating applied to metal components to increase their resistance to corrosion and oxidation. Such a coating, developed by the U.S. National Bureau of Standards, has been used extensively on aircraft and vehicle exhaust systems with excellent results.

Ceramals, or ceramets, are a combination of ceramics and metals that are pressed and sintered, or hot-pressed. By such a combination it is attempted to combine the good high-temperature resistance and low density of the ceramic with the good resistance to thermal shock and the ductility of the metal. There is a certain optimum ratio of the two components. Various carbides have been tried. Boron carbide has an extremely poor resistance to oxidation above 870 deg. Cent. Titanium carbide is the most promising. A ceramal containing 80 per cent titanium carbide and 20 per cent of cobalt had a (modulus-of-rupture) strength of 26 tons to 45 tons per square inch at 870 deg. Cent. and 13 tons to 32 tons per square inch at 1090 deg. Cent. Nickel is nearly as good a binder as cobalt, but iron has been found to be less effective. Another ceramal composed of 90 per cent titanium carbide and 10 per cent molybdenum had a strength of 7 tons to 9 tons per square inch at 1315 deg. Cent. The oxidation characteristics of titanium carbide ceramals were found to limit service life at 1315 deg. Cent. to ten hours, necessitating an oxidation-resistant ceramic coating for longer life. As many of the ceramals have a high thermal conductivity, it will be necessary to provide better cooling of the turbine wheel when ceramal rotor blades are used, or of the stator case when ceramal stator blades are used. It would appear that turbine stator blades made from ceramals are now feasible.

Cooling

Cooling of the gas turbine engine components exposed to the hot gas is the only means by which marked increase in turbine inlet temperatures is likely to be achieved in the near future. Cooling may also be used to reduce the amount of scarce or expensive alloy elements in the gas turbine engine, while retaining present operating temperatures. Such components as turbine blades and discs, stationary nozzles or fixed blades, connecting ducting, turbine stator case and combustion chamber liner will require new or improved cooling methods. The most difficult component to cool from a mechanical and thermal standpoint will be the turbine blades. The methods examined in the paper are internal and boundary layer air cooling, transpiration or sweat cooling, internal liquid cooling spraying and water pad cooling. Air cooling is inherently simpler, but water cooling is the more effective. With internal water cooling of blades, however, impurities and rust in the water circuit may plug the blade passages with resultant stoppage of water circulation and blade failure, though suitable inhibitors may prevent or reduce corrosion in the water circuit. It appears that transpiration cooling will permit the highest maximum turbine inlet temperatures. The main problem in developing transpiration cooling is the production of materials with uniform porosity and the required mechanical strength. Such materials are most likely to be produced by powder metallurgy methods.

Fuels: Corrosion

A considerable section of the paper deals with fuels, and in particular with the corrosion which results from the burning of residual fuel oil, upon the use of which widespread application of the gas turbine engine for industrial, locomotive and merchant marine service is likely to depend. Corrosion results from the presence of vanadium in various forms including vanadium pentoxide, certain sodium salts, especially the sulphate, and from sulphur present in the fuel ash. A number of methods exist or have been suggested by which the adverse effects of vanadium, sodium and sulphur may be minimised and, it is to be hoped, eventually eliminated. The paper mentions a dozen of these, among them being additions to the fuel, coating of blades, cooling of blades and incomplete combustion. It is possible that the addition of certain metallic oxides (e.g. CaO, ZnO, MgO, &c.) to the fuel will minimise the vanadium attack by forming vanadates having very high melting points. Care must, however, be taken to introduce the proper amount of any addition so as to avoid the formation of low melting point eutectics and the production of ash, necessarily increased in amount, of such a nature as to stick to the blades. Coating the parts subjected to high temperatures is another promising method. Chromising, siliconising and aluminium metallising have been tried. Even a chalk coating considerably reduced the attack. Boundary layer or sweat cooling of the blades, if effectively done, should prevent corrosion because they insulate the blade surface from contact with the combustion gases and also cool the surface itself. It has been reported that incomplete combustion, resulting in the deposit of soot, will reduce the rate of attack, but this method of deliberately promoting poor combustion would normally be undesirable.

It is unlikely that any alloy will be found which will resist the attack of all possible residual fuels at all temperatures, though some alloys, e.g. those containing large percentages of molybdenum or vanadium, are known to be specially susceptible to attack. There is, moreover, at present, no distillation process which will remove vanadium from residual petroleum economically. Any solution of the problem will also benefit residual fuel burning high-temperature boilers and diesel engines which experience some of the same difficulties from sodium and vanadium attack as are found in the gas turbine engine.

This well-documented review, with ninety-seven references to published information which forms the basis of the text, is typical of the other sections of the Gas Turbine Progress Report dealing with the design and development of gas turbine engines for aircraft, marine, locomotive and industrial purposes.

Silicon

A study of the non-metallic element silicon has been made at the Illinois Institute of Technology, Chicago, on behalf of the U.S. Air Force. Enormous use is made of silica and silicates. Silicon itself, in the form of silicon-rich materials, is used as a deoxidising agent in steelmaking, and also as an alloying element in iron, aluminium, copper and nickel alloys. Silicon of high purity could be made available at low cost; it has a density lower than that of aluminium and a high resistance to oxidation and corrosion; but, in spite of these advantages, it does not appear to offer any promise as an engineering material. It possesses the typical brittle characteristics of a diamond crystal structure. It is hard and retains considerable hardness at high temperatures, but without any evidence of plastic deformation. Furthermore, all silicon-rich alloys appear to be two-phase with brittle silicon as the major constituent. This appraisal of silicon and its alloys is contained in an article by W. R. Johnson and M. Hansen* which summarises the detailed information to be found in U.S.A.F. Technical Report 6383.

Effect of Hydrogen on Iron

In the course of the last thirty years problems associated with the effect of hydrogen on iron and steel have been the subject of many researches. The practical objective of most of these has been the elimination of the detrimental effect of hydrogen in the pickling process, in welding procedure, in the manufacture of ingots and forgings and on the tensile properties of cast and wrought steels. At the same time other investigations of a more academic character have been carried out, throwing light on the subject and contributing information which must be taken into account in framing any theories of the general effect of hydrogen on steel. An investigation of this kind is a study of the supersaturation of iron by cathodic hydrogen, recently reported by Dr. Jean Duflot.† By cathodically charging electrolytically polished soft iron with hydrogen he was able to supersaturate the metal consistently with large volumes of hydrogen of the order of 130ml to 140ml per 100g. The effect of structure and of prior mechanical and heat-treatment was studied; but, as soft iron only was concerned, the variations observed were due only to modified conditions at grain boundaries, in mosaic blocks and at slip planes, and not, for example, to changes in the character of pearlite which might exercise an effect in mild steel. During the first few minutes of cathodic charging, blisters became visible on the surface, micro-blisters in large grains having a geometrical form, often square; and subsequently internal flaws developed, roughly parallel to the surface of rolled strip and involving intercrystalline and transcrystalline rupture of the material. Microscopical examination and micro-hardness tests revealed evidence of a "cold-working" effect in the vicinity of these defects, due to the pressure of molecular hydrogen which had caused rupture of the steel. The general hardness rose from 55 to 65 Brinell after eight hours' charging, but locally the hardness rose to 80 or more. The most striking feature of the tensile tests was the fall in elongation from 22 to 2 per cent after two hours' charging. Owing to the permanent damage sustained it was only partially restored by degassing at 115 deg. Cent. The report illustrates the mechanism and some of the results of excessive hydrogen absorption in iron, without adding to existing knowledge of how to combat the detrimental effects of hydrogen in commercial practice.

Welding of Aluminium Alloys.—Demonstrations of the welding of aluminium alloys by the latest production techniques are being arranged by the Northern Aluminium Company, Ltd., Banbury, at various centres throughout the country. The shielded inert gas metal arc and argon tungsten arc processes will be demonstrated followed by two films entitled "Aircomatic Welding" and "The Study of Arcs in Sigma Welding." The first demonstration took place on March 18th at the Government Training Centre, Slough, and others were held on Wednesday, March 25th at the Government Training Centre, Bilton Way, Ordnance Road, Enfield Highway, Middlesex; another will be on April 1st, at the Southampton Technical College. Subsequent demonstrations are being arranged at Bristol, Cardiff, Birmingham, Liverpool, Manchester, Leeds, Sheffield, Newcastle and Glasgow.

Cold Extrusion of Steel.—As a result of the considerable interest being shown in this country in connection with the cold extrusion of steel components, the Sheet and Strip Metal Users' Technical Association has arranged a two-day conference on the subject to be held on May 12th and 13th at the Royal Empire Society, in London. The papers to be presented on the various problems associated with cold extrusion of steel will include the following:—"Principles and Practice of the Cold Extrusion of Steel," by Dipl.-Ing. H. Fischer; "Power Presses for Cold Extrusion," by Mr. A. E. Clements and Mr. E. V. Crane; "Die Steels for Cold Extrusion," by Mr. E. Bishop and Mr. E. Johnson; "Phosphate Coatings for Assisting Cold Extrusion: A Review," by Mr. H. A. Holden, and "Metallurgical Requirements in Steels for Cold Extrusion," by Mr. D. V. Wilson. Full details of the conference and application forms for tickets are obtainable from the honorary secretary of the association at 49, Wellington Street, London, W.C.2.

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* *Metal Progress*, February, 1953, page 105.

† *Contribution à l'étude de la Sursaturation du Fer en Hydrogène Cathodique*, by Jean Duflot. Service de Documentation et d'Information Technique de l'Aéronautique.

THE ENGINEER

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Death of Queen Mary

THE death of H.M. Queen Mary means neither more nor less to engineers than to those practising other professions and trades. For she had no special interests in engineering. Yet how much her death means! When Princess May married the Duke of York, who was to become King George V, the Victorian era was drawing to a close. Already Britain was losing its pre-eminence as the workshop of the world. But great changes were on their way to being brought about by engineers. The era of electricity, of the motor-car and the aeroplane was dawning and immense social changes were impending. But through all those changes as they came, and through the convulsions of two world wars, Queen Mary upheld and steadily maintained a belief that necessary adaptations to changing circumstances need not and should not alter the basic modes and decencies of behaviour. Queen Victoria in her lifetime created the modern conception of monarchy as one of domestic felicity combined with untiring service to her people. Queen Mary in hers helped to harden that conception into a tradition that will support her granddaughter and all who follow her upon the Throne. She did more. Somehow, perhaps in the courage with which she overcame a shyness and reserve that was natural to her, perhaps in her ways of living and speaking and doing in times of joy and those many days of sorrow that beset her, she epitomised the indomitability of the British people, besides many other virtues they hold dear. A very great lady as well as a great and gracious Queen has passed from the stage.

Contents

LEADING ARTICLES—
Productivity Conference ... 462
Naval Gas Turbines ... 463

ARTICLES—
Admiralty Test House for Gas Turbines. (Illus.) ... 452
Annual Report of the D.S.I.R. ... 445
Automatic Control of Open-Hearth Furnaces. (Illus.) ... 456
Bolt and Nut Reclamation System. (Illus.) ... 475
B.S.R.A. Resistance Experiments on the "Lucy Ashton." No. I. (Illus.) ... 467
Compaction of a Rock Fill Dam ... 455
Duty-Free Machinery Imports ... 445
Electronic Control for Glass Grinding Machine. (Illus.) ... 458
Emergency Flood Works on the Eastern Region of British Railways ... 470
Erection of a Railway Bridge. (Illus.) ... 469
Exhibition of Electrical Engineering ... 469
Factory Equipment Exhibition ... 445
Flood Investigation Committee ... 445
Fuel Conversion Equipment ... 476
High-Temperature Tube Furnace. (Illus.) ... 459
Induction Stirrers for Electric Arc Furnaces ... 469
Machine Tool Trades Association ... 464
Photo-Elastic Techniques ... 465
Silicone Resins in Insulation at Power Frequencies. (Illus.) ... 471
Soap Stream Divider. (Illus.) ... 476
Steel Castings Research ... 445
Steel Founders Convention ... 445
Training of Radiologists for Industry ... 448
Universal Contour Forming Machine. (Illus.) 475
Water Power in the Italian Alps. No. VII. (Illus.) ... 446

METALLURGICAL TOPICS—
High-Strength Steel Castings ... 460
Materials for Gas Turbines ... 460
Silicon ... 461
Effect of Hydrogen on Iron ... 461

LETTERS TO THE EDITOR—
Installation of Long Conductor Rails on Southern Railway ... 464
Library Service for Industry ... 464

OBITUARY—
Dempster Smith, M.B.E. ... 463
Andrew Gray ... 464
Bertram C. Joy ... 464

NEWS AND NOTES—
African Engineering News ... 476
American Engineering News. (Illus.) ... 473
Books of Reference ... 470
British Patent Specifications. (Illus.) ... 479
British Standards Institution ... 480
Codes of Practice ... 480
Forthcoming Engagements ... 480
Industrial and Labour Notes ... 477
Launches and Trial Trips ... 478
Notes and Memoranda ... 478
Personal and Business ... 478
Technical Reports ... 473

THE PRODUCTIVITY CONFERENCE

At the end of last October, the British Productivity Council was formally established to take over the work of the United Kingdom section of the Anglo-American Council on Productivity, and also to engage in fresh activities designed to assist the industrial productivity of this country. The Council consists of representatives of the British Employers Confederation, the Federation of British Industries, the Trades Union Congress, the Association of British Chambers of Commerce, the National Union of Manufacturers, and the nationalised industries. On Thursday of last week, the Council convened a conference in London, at which its "programme of action" was announced. More than a thousand people spent the day at the conference. They included many of the members of the sixty-six productivity teams which have visited the U.S.A., representatives of both sides of the industries which have sponsored those teams, and representatives of employers' associations, trade unions, and other interested organisations. Throughout the morning they gave close attention to some excellent speeches by the chairman and deputy chairman of the Council, Sir Peter Bennett and Sir Lincoln Evans, by the Chancellor of the Exchequer, Mr. R. A. Butler, and by Sir Ewart Smith, who stressed the Council's objective as being "to stimulate the improvement of productivity in every sector of the national economy by every possible means."

The British Productivity Council represents management and workers in every kind of industrial activity. It is non-political, free of Government control, and is concerned only with the improvement of the economic position for the betterment of all. In the improvement of productivity, the Council has declared, every working member of the community has an opportunity and a responsibility, as well as a personal interest in its ultimate success. The programme of action was outlined at the conference by Sir Norman Kipping. The first proposal is what the Council calls a "circuit scheme," in which individual firms are being invited to enter a team of six, consisting of two from management, two from staff, and two from the shops, to be sent once a month to visit another team in the same circuit. The firms participating in the scheme undertake to receive a team from each other at monthly intervals, the object being to exchange knowledge and experience of methods and techniques. It is intended that each circuit shall be composed of about ten teams, based on geographical convenience and size of establishment. The second item in the Council's programme is the establishment, in 105 towns and districts of the United Kingdom, of local productivity committees. The Council is anxious "to leave a very great deal of initiative and freedom to these committees to work out their own methods," but it proposes to help them with printed material, lecturers and films, and with some financial aid. A third activity under the programme is to be the preparation of a series of short films emphasising—to the public in general rather than to industrial workers alone—the importance of productivity. Of these three proposals it is our impression that the first is likely to prove more valuable than the others. For regular works visits by teams including representatives from the shop floor, who seldom have the chance to see how production is carried on elsewhere, may well lead to a fruitful interchanges of ideas and criticisms; and those interchanges will take place on the actual shop floors of the firms concerned and are, likely to prove greatly more valuable than hours of more formal committee discussion. We confess, indeed, for that very reason, to much doubt about the value of the Council's proposal to set up new productivity committees up and down the country. As was pointed out by several speakers at the conference, improved productivity now depends upon creating an atmosphere amongst all those engaged in industry. That is the reason why it is proposed to include the preparation of films suitable for the general public amongst the Council's activities. As Sir Lincoln Evans put it, "to achieve higher productivity is not only a matter of providing the right machines and knowing the right techniques, essential as they are; it is as much as anything a question of acquiring the right attitude of mind."

It was the intention that the afternoon session of the conference should be devoted to a general discussion on the Council's programme of action. There was certainly no lack of discussion. In the space of about two

hours more than a score of speakers took their turn at the microphone. But, whilst keeping more or less to the subject of productivity, they wandered in their remarks far from the Council's programme ; and only two or three of the speakers, in fact, mentioned the programme at all ! That discussion did, however, bring out very plainly that there are still leaders amongst the men who are unconvinced of the value to their followers of enhanced productivity and suspicious of the motives of industrialists who try to bring it about. Although there were some trade union officials who quickly made it clear that they supported the views of Sir Lincoln Evans, there were others who made it equally clear that they did not ; and there is no doubt whatever that in doing so they reflected the opinions of large numbers amongst the workers. For the old suspicions of new machinery and new methods and the old fears that higher unemployment is the necessary consequence of higher productivity are very far from dead. Luddite arguments can still be heard in the land. Nor are those suspicions and fears wholly unreasonable. Many hundreds of thousands of men in industry to-day have not forgotten the miseries of unemployment twenty years ago. Executives as a whole have long since become convinced of the advantages to themselves as individuals, as well as to their firms and the nation at large of pressing productivity higher. But many of the workers in the shops remain unsure about the benefits they would experience. If the Council, through its work, can carry more conviction on to the shop floor it will have done great service. But, alone, it cannot hope for success. If its work is to be effective not only must individual firms avoid, as far as possible, doing anything likely to renew suspicions and fears that have been lying more dormant latterly than before the war, but the Government itself must play its part. If the workers are to be convinced of the virtues to themselves of enhanced productivity, the Government must maintain, so far as it is able, an economic climate that encourages increased output and ensures that that output will be taken up. For if increased productivity did bring about substantially higher unemployment those wiser leaders of the men who are now preaching its virtues to their followers would be discredited and no amount of preaching by the Council could then prove effective.

NAVAL GAS TURBINES

The new test house for naval gas turbines, described and illustrated on another page of this issue, is not in itself a self-contained research establishment. Its purpose, obviously enough, is not to bring about directly developments in gas turbine design, but to test machinery designed and constructed elsewhere for naval purposes and to discover its characteristics and, if it has any, its weaknesses. The value of such testing of marine machinery upon land has already been demonstrated by the work of Pametrada upon steam turbines. It should prove even more valuable for gas turbines, in the design of which there is much less experience to act as a guide than there is with steam turbines. The source of " teething " troubles can be more easily found by land testing than by testing at sea, and those troubles can be eradicated before the machinery is actually installed in a naval vessel. Research intended to improve knowledge about gas turbines can be and is apparently intended to be left to the National Gas Turbine Establishment, with which the test house is so closely associated, to Pametrada, Power Jets and other research bodies, and to the work of individual gas turbine builders.

But if the objective of the new plant is thus limited, it is still likely to prove of very great value to individual gas turbine makers. For in the testing of gas turbines there is the obvious difficulty that the power developed appears as the difference between two substantially larger powers. The compressor of the Allen 1000kW auxiliary set now undergoing test at the new station absorbs, for example, 4000 h.p. Thus, though a small firm may be adequately equipped to test its set as a whole, it may find it difficult, if not impossible, satisfactorily to test the individual units separately. That is work the new test house is capable of undertaking. Furthermore, only very few manufacturing concerns could afford to allow a gas turbine set to occupy valuable space in a test bay for the prolonged test periods envisaged by the Admiralty and undertaken to establish not merely the characteristic behaviour of the machinery, but its reliability under service conditions. Nor probably are there many industrial test beds so comprehensively equipped with instruments. Much valuable information is thus likely to flow back from the new establishment to firms whose products are tested there. At sea, and more particularly, perhaps, for naval purposes, the prospects of success for the gas turbine could already be seen to be bright when a Metrovick "Gatric" unit was installed in a gunboat and gave encouraging results, despite the fact that it was an aircraft unit adapted for marine use rather than a machine designed *de novo* as a propulsion unit. Since then the gas turbine set built by the B.T.H. Company and installed in the M.V. " Auris " has proved sufficiently successful to encourage the Shell group to order a tanker to be propelled wholly by gas turbine engines. Now there comes the announcement about the setting up of a Naval Marine Wing at the National Gas Turbine Establishment and the building of the new test house. These developments clearly suggest that the Navy has become really impressed by the possibilities of gas turbines for the propulsion of ships and the generation of auxiliary power. For unless the Admiralty seriously believed that propulsion sets up to 10,000 h.p. were capable of development and were really likely to prove advantageous for naval service, it would surely not have taken those actions, but would have been content to leave the testing of gas turbine machinery to Pametrada and individual manufacturers. That it really is impressed was emphasised by Sir Michael Denny, Third Sea Lord, when he recently visited the test house. For he spoke of " important decisions concerning the future of the gas turbine in the Royal Navy " as having been made ; and of " the consequences of these decisions " proving " as revolutionary as the partial supercession of the steam reciprocating engine, at the turn of the century, by the steam turbine."

Sir Michael did not reveal very precisely what he had in mind. But he did say that ships would have gas turbine power generating sets in the very near future. For that purpose, no doubt, gas turbines have the advantages that they can be lighter and more compact than steam sets and that they can be independent of the main boilers. But what was more exciting in his comments was the suggestion not only that smaller ships would " undoubtedly " have gas turbine propulsion, but that gas turbine engines might be installed alongside steam turbines for the propulsion of larger vessels. Here no doubt the advantage would lie in fuel economy. For steam machinery designers would be relieved of the necessity to provide turbines capable of high power output, at rather low economy, in addition to an economical cruising power. The gas turbine engines would be utilised only to provide the extra power needed for high speeds ; so that at those speeds the steam and the gas turbine propulsion units would both be operating near the peaks of their respective efficiency curves. The familiar difficulty of providing for the astern operation of gas turbine engines would also be evaded in that way, since that responsibility would no doubt rest upon the steam machinery. But Sir Michael did not reveal how it is intended to link in the gas turbine sets. In gunboats having oil or petrol engines for cruising and a gas turbine set for full power the latter drives its own central propeller. But other arrangements are possible. Electric drive may be envisaged, as in the " Auris ; " or the gas turbine drive might be engaged through some form of hydraulic coupling. No doubt that problem has been and is being studied. Probably experiment will be needed to resolve it. Certainly it is not insoluble. What is clear is that the Admiralty is convinced that gas turbines can be quickly developed for naval service. In other fields, in rail traction, generation of power for the grid and for other industrial purposes for which its qualities may well fit it, the gas turbine has still to prove its superiority to other means of power generation and it is still impossible to assess its chance of doing so. But, at least in the opinion of the Admiralty, success at sea is already assured.

Obituary

DEMPSTER SMITH, M.B.E.

We have learned with deep regret of the death of Emeritus Professor Dempster Smith, which occurred at 6, Maule Terrace, Gullane, East Lothian, on Saturday last, March 21st. Until his retirement during the war years, he had been for a long period Professor of Mechanical Engineering at the Manchester College of Technology. He will be particularly well remembered by his active participation in the affairs of the profession of mechanical engineering in the North-West.

Dempster Smith was born on February 6, 1874, and was educated at the English School, Perth, and at the Glasgow and West of Scotland College. He served a five-year apprenticeship with Sharp Stewart and Co., Glasgow, and on its completion continued with that firm for three years, during the latter part of which he was chief draughtsman in the machine tool department. Dempster Smith then spent three years on the design staff of Sir W. G. Armstrong Whitworth and Co., Ltd., after which he went to Manchester to take up a post as chief designer

with Hulse and Co., Ltd. That appointment he relinquished in 1902 on becoming a lecturer in mechanical engineering and a demonstrator in the laboratories at the Manchester College of Technology. It was this appointment that marked the beginning of Dempster Smith's long period of distinguished service—extending over forty years—to the College of Technology. There was only one break in Professor Smith's long career as a teacher of engineering. It occurred during the first world war, when for two years he served as works manager with Mirrlees, Bickerton and Day, Ltd., at Stockport. Upon his retirement from the Manchester College of Technology, Dempster Smith received the title of Emeritus Professor.

Professor Smith was elected an associate member of the Institution of Mechanical Engineers in 1907, and a full member in 1913. He did much to assist the work of the Institution and contributed several papers to its *Proceedings*. He served on the cutting tools research committee set up by the Institution in 1920, was for many years a member of council, and was also for some time the honorary secretary of the North-Western Branch. In recognition of these and many other services which he rendered to the Institution, the council elected him to honorary membership in 1941. Professor Smith also took an active share in the work of the Manchester Association of Engineers, of which he was a past-president. His contributions to technical literature included books on *Lathe Design* and *Engineers' Costs and Economical Workshop Production*, and, in collaboration with Professor J. T. Nicholson, a lengthy series of articles on "The Rational Design of Machine Tools," which appeared in THE ENGINEER in 1912.

ANDREW GRAY

WE regret to announce the death at Brentford (Middlesex) Hospital on Sunday of Mr. Andrew Gray, who was one of the pioneers of wireless telegraphy, and a personal friend and assistant of the late Marchese Guglielmo Marconi. Mr. Gray, was was eighty, had lived in West London since his retirement twenty-one years ago.

Andrew Gray was born at Glasgow and graduated at Glasgow University. Later he took a diploma in electrical engineering at the Glasgow and West of Scotland Technical College, and then became assistant to the late Professor Andrew Jamieson.

In 1895 he joined the staff of the West India and Panama Telegraph Company, Ltd., as assistant electrician, and became chief electrician and, later, as telegraph engineer, he was responsible for the condition of 7000 miles of cable. It was in 1899 that Mr. Gray first joined the Marconi Company two years after its formation, and started immediately as personal assistant to Marconi ; he was particularly active in tests between the Isle of Wight and the mainland in the tuning of wireless circuits whereby multiplex and duplex working were made possible. At the turn of the century Mr. Gray introduced the Marconi system of wireless intercommunication in the Hawaiian group of islands, organising and training local operators. In 1901 he was appointed chief of staff to the company and, because of his cable and telegraph experience, was put in charge of the training of new engineers and the organisation of ship and shore wireless communication of the Marconi International Marine Communication Company, Ltd. This company took over its own telegraph operating in 1906, but until 1919 Mr. Gray continued to supervise the testing and installation of wireless on ships. Meanwhile, as chief of staff, Mr. Gray was also responsible for design, testing, installation and working of all the wireless company's stations and also development of patents for the parent and associated companies. He was appointed chief engineer to the company in 1910, joint general manager in 1923, and technical general manager in 1928.

BERTRAM C. JOY

WE regret to record the death of Mr. Bertram Charles Joy, M.I.Mech.E., of Bank House, Montgomery, which occurred on Friday, March 20th. He was seventy-seven, and throughout the whole of his professional career was associated with the British automobile engineering industry. Bertram Joy was the second son of the late David Joy, and was educated at Aldenham School and at University College, London. After a period of practical engineering under his father, he joined the Simms Manufacturing Company in 1896, and for eleven years or so was engaged on motor-car and engine design. Mr. Joy then started up in practice as a consultant, in which work he continued until the early 1930s, apart from a period of eighteen months or so in the first world war when he served as chief draughtsman to the Associated Equipment Company, Ltd. When he relinquished his consulting work, Mr. Joy joined Simms Motor Units, Ltd., his principal responsibility being experimental and development work on car and engine accessories. There are several inventions to his credit, including gas and vacuum pumps, a diaphragm fuel pump and a magnetic oil filter.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

LIBRARY SERVICE FOR INDUSTRY

SIR,—Mr. Fullman's contention that there are occasions when the librarian is unable to help industry is probably correct, but I think they are far less frequent than he seems to imagine. Experience based on a research association is not typical, because many inquiries received there are those which the ordinary channels of inquiry have failed to satisfy, and which have already been subjected to extensive searches in works' and public technical libraries. The fact that many of them cannot be answered in the research association library, even with the large amount of special material assembled there, is not surprising, and indicates that a system whereby local sources are tried before a specialist organisation is appealed to is working satisfactorily, and to turn to the research man is a natural consequence.

But only a fraction of the inquiries, even of the kind which Mr. Fullman describes, which is received at works' and public technical libraries is passed on to the research association. A large proportion of them are dealt with to the satisfaction of the inquirer by recourse to literary sources, which are frequently considerable. When experts are available, as in many large firms, they are naturally appealed to, and unanswered inquiries are in appropriate instances referred to sources of information further afield, such as a research association or D.S.I.R. Thus, the library acts not only as a local centre to which industrial inquiries can be directed, but as a link with special sources of information. It is the combination of these functions which makes the value of the library's services to industry of special significance, and which makes it not only the most appropriate, but in many areas the only possible, agency for handling industrial inquiries. I am not suggesting that the library service is everywhere all it should be. But where these functions are conscientiously carried out their value can hardly be doubted when industry is turning more and more to libraries for the solution of its problems.

A more complete and effective local library service would probably eliminate many of the inquiries of a routine character, which, according to Mr. Fullman, are received at a research association, but which could be satisfactorily dealt with earlier in the chain of responsibility for technical information. But in this connection there is one point which should be borne in mind. Much technical information is not available to public libraries and similar institutions either for commercial or for security reasons. It is often for lack of material of this kind that the public librarian, however willing to help, is obliged to refer his inquirer to another source.

When making a general survey of a subject such as this, the use of generalisations like the one to which Mr. A. R. Smith takes exception is at times unavoidable. The fact that they do not fit an individual case does not disturb their general truth. The extent to which the library is concerned with the interpretation of information naturally varies from organisation to organisation. In my article I used the expression "The value, and even the functions, of a library are by no means universally understood." From Mr. A. R. Smith's letter it is evident that he has also missed the point of my argument.

K. J. RIDER

Birmingham, March 17th.

INSTALLATION OF LONG CONDUCTOR RAILS ON SOUTHERN RAILWAY

SIR,—The article which appeared in your journal on March 6th, illustrating new methods and equipment for the handling of long conductor rails on the Southern Railway, appears to convey the idea that the method of off-loading rails is new.

The pulling off tackle was in use on the old Great Western Railway between fifteen to twenty years ago. The disadvantage was that the ends of long rails were frequently crippled in their fall from the rail wagons. To overcome this difficulty, the writer, in collaboration with Mr. Neale, divisional engineer, Oswestry, designed a chute in 1944 for breaking this fall, and it does seem from the illustration that the chute at present in use is identical with the one designed and fabricated in 1944, with the exception of one or two minor structural details.

Watford, March 17th. W. T. WILKS

Machine Tool Trades Association

LAST Tuesday night the Machine Tool Trades Association held its annual dinner at the Dorchester Hotel, London. The toast of "The Guests" was proposed by the president, Mr. Robert Asquith. He remarked that international commerce was in bad health, and suggested that "faith healing" ought to be tried as a cure. At present France could not buy machine tools from Britain because Britain did not buy other things from France. He was glad to learn of recent news towards freer trade with that country. But Britain still prevented the admission of machine tools from America, while admitting them from elsewhere. Was that protection or was it not ? The Americans might be excused for thinking that it was. In reply, Lord Piercy, chairman of the Industrial and Commercial Finance Corporation, Ltd., referred to Government policy restricting the rate at which industry could re-equip itself with machine tools. There were some signs of a change of policy. Industry would like to see depreciation allowances revised. For arrangements in this country for writing down capital were less liberal than in America and elsewhere. The toast of "The Machine Tools Trades Association" was amusingly proposed by Sir James Helmore, Permanent Secretary, Ministry of Supply. In reply, Sir Lionel Kearns, a past-president of the Association, said that so far as the Association was concerned, all tariffs on machine tools could be taken off. The industry could continue to live without them.

Photo - Elastic Techniques

THE INSTITUTION OF MECHANICAL ENGINEERS

AT a general meeting of the Institution of Mechanical Engineers, held last Friday, March 20th, the following papers were presented and discussed :—

A ROOM TEMPERATURE PHOTO-ELASTIC TECHNIQUE FOR THREE-DIMENSIONAL PROBLEMS

By J. H. LAMBLE, M.Eng., Ph.D., M.I.Mech.E., and SALAH E. A. BAYOUMI, B.Sc., (Eng.), Ph.D.

For the application of photo-elasticity to the stress analysis of three-dimensional problems the existing methods rely on the "stress-freezing" property of thermosetting resins. This again requires the model material to have certain characteristics that are not always present. The lack of these leads to experimental difficulties that may be overcome only by skilful technique.

In the "sandwich" method described in the paper, the difficulties associated with stress-freezing—as, for example, large distortion of the model and rind effect—are avoided by loading at room temperature. In addition a series of fringe patterns is obtained for the specific plane selected for investigation, as distinct from one pattern only for a frozen slice. These patterns are repeatable for the same loading. The difficulties that arise in the production of a sandwich in "Perspex," with "Catalin 800" as the birefringent layer, are discussed in detail. It is emphasised that, before it is made up into the sandwich, the "Catalin 800" must be subjected to additional curing to bring its elastic properties into line with those of "Perspex"; this also improves its behaviour at room temperature.

Semi-circular notches on round bars subjected to axial tension have been selected to demonstrate the correctness of the solutions obtained, and the results are in good agreement with those predicted by Neuber (1945). The method has been applied also to the case of a thick cylinder under internal pressure, to investigate the increased stresses arising at a diametral port, and also to the estimation of the stress distribution in nut and bolt assemblies.

Despite certain limitations met with in each particular application, it is evident that the "composite model technique" described in the paper provides a very useful tool for stress analysis in three-dimensional problems.

THE USE OF GELATIN MODELS IN STRUCTURAL ANALYSIS

By JOHN D. C. CRISP, B.E.

The thesis of this paper is that gelatin in photo-elasticity can be applied successfully as a potent means of quantitative stress analysis of body-force structures capable of representation as plane elastic problems. A valid simulation of a prototype is derived, in general terms, in accordance with similarity principles and the choice of model materials shown to be vital in any particular application. Details of model construction are given and mention is made of the important influence of model thickness, temperature control, and polariscope design, on the attainable accuracy of calibration and stress patterns. The exposition is illustrated by reference to the problem of the elastic, untied, bulkhead that retains an elastic mass by virtue of its flexural rigidity. Curves of pressure distributions derived from model analyses are included.

DISCUSSION

Dr. R. B. Heywood said that the papers before the meeting described two new photo-elastic techniques. The paper by Lamble and Bayoumi proposed a third method of three-dimensional photo-elastic technique, the other two methods being the scattered light method and the frozen stress method. He was not entirely happy about the way in which, in the introduction to the paper, the frozen stress method was described. He felt that the authors had been a little unkind to the method in order to boost up the new technique. The advantage of the method described in the paper was that several readings could be obtained from the same model, so that even if one did have spurious effects present one could eliminate them in that way. For example, the graphs in the paper demonstrated very nicely how one could smooth out the points by plotting graphically; in fact, the graphs need not really have passed through the origin and the slopes would still have given the correct answer. He felt that the authors had very good grounds for recommending the new technique. He had been rather interested in what was really a sideline of the work that had been done in connection with the curing of Catalin. He felt that the work done there could be quite important not only in connection with this technique but also for other occasions, such as room temperature and perhaps for the freezing method as well. He was very much interested in the detailed results obtained from the curing method. The material fringe value was constant for different values of E. That was a very pleasant and surprising result. Previously the only figures he had seen quoted on this were those given by Hendry for curing or annealing—whatever one liked to call it—for twenty hours at 80 deg. Cent. in oil; Hendry claimed that the fringe stress coefficient was doubled with this treatment and that the creep properties were reduced to a quarter, so that there was a corresponding gain but it was nothing like the gain that the authors claimed in the present paper. In effect, by carrying out this heat treatment the authors were obtaining a very much better material.

In the paper a few formulæ were given for assessing the effect of the fringes in the slice. He noted that the whole of the analysis was done for homogeneous stress and for the case that was mentioned, stress at the centre of the bar, the stress would not be homogeneous, and he would like to hear the authors' suggestions on how they would overcome that difficulty. It seemed to him that because the stress was not uniform the percentage of 18 per cent was in doubt. There was another minor point worthy of mention. He remembered reading in an American paper by Robinson and one or two other people that the methyl methacrylate type of resins had a negative fringe stress coefficient, and he wondered whether that would apply to the materials that had been used by the authors. In other words, if it were a negative coefficient, the value of f_σ would be reversed in sign; but the same formula would apply. He would like to have a little clarification on the question whether the sensitive slice should be placed on the symmetrical plane and whether the method could be extended to other cases in which one had a combination of three-dimensional model and the slice was placed in a random direction, and whether further analysis could be done by using the oblique incidence method.

As to the second paper, he thought that Mr. Crisp was to be congratulated on tackling the difficult question of the laws of similarity and that he had been very wise to include an example, because it was all very nice to see these general laws, but when one came to analyse the details and apply the results, one usually got into some difficulty. The author had very kindly given a relatively complicated example in which there were two different materials involved. Although gelatin was a very old material, not a lot was known about it and if the author could give some information on the properties of gelatin it would be of interest. For example, one of the things about which he was wondering was what happened to the material after it was cast. Was some form of initial stress present? Another point of interest was the behaviour of gelatin with time. He understood that it was left for twenty-four hours cold, but it would be of interest to know how the properties varied thereafter. Would the material fringe value be the same after a few weeks, for example?

He was glad that the author had described his technique of using the gelatin and it was nice to know that in general the author confirmed the findings of Farquharson and Hennes. He was also glad that the author favoured the diffuse light polariscope, which had considerable advantages in its simplicity.

Mr. A. F. C. Brown said that he wished to make a few comments on the paper by Lamble and Bayoumi because, in about 1948, they had been very interested at the National Physical Laboratory in the possibilities of the "sandwich" method. The attraction of using two grades of methyl methacrylate, one photo-elastic and the other non-photo-elastic, was that they had hoped to make a perfectly homogeneous composite model. They had made a number of tests on the mechanical and optical properties of the two materials and found the greatest stumbling block was not in matching the Young's moduli of the two materials, but that it lay rather in their unsuitable photo-elastic properties. The authors had already remarked that birefringent Perspex was not sufficiently sensitive. At the N.P.L. they had thought that this would not matter so much if the kind which was supposed not to be birefringent was really insensitive to stress. The ratio of sensitivities was only four or five times, and this ratio varied with time of loading, the optical creep characteristics of the two materials being different. He was very glad to know that a successful solution to this problem had now been found by the use of Catalin suitably cured to give it a modulus equal to that of the Perspex. There was one great advantage which the "sandwich" method possessed over the frozen stress method, and that was in the use of model material which had a Poisson's ratio nearer to that of the metal which it represented. If the authors had the information, it would be interesting if they could say what the Poisson's ratios were for the Catalin and Perspex which they had used. For the normally used frozen stress materials such as Fosterite and Bakelite B.T. 61–893, the figure was about 0·5, and it was not yet certain how much effect this difference from, say, 0·3 made to the stress distribution. The only exact three-dimensional stress analysis which had been published was that due to Neuber, and this showed that, in the case of a deep hyperbolic notch, the main effect of a change in Poisson's ratio was on stresses perpendicular to the direction of the applied load. There was, however, some reason to believe that this was not always so, and the "sandwich" method might prove to be a valuable method, not only in itself, but as a check on the results of frozen stress investigations.

Mr. R. J. Wilkins referred to the paper by Mr. Crisp. In that paper the photo-elastic method was applied to a specific problem concerning the pressure of a soil, and the value of the quantitative results obtained must be judged against the real properties of the soil causing pressure on the actual structure. The author was apparently well aware of those factors, and had referred to his problems as that of the flexible untied bulkhead subjected to horizontal pressures from an elastic fill. It would be readily understood that the civil engineer had to consider a number of soil properties, such as density variation, degree of soil compaction, internal friction, cohesive forces in the fill, presence of moisture and friction on

the structure, &c., in his assessment of the loading pressures. An essential condition of the photo-elastic approach was stated to be the maintenance of frictionless contact in the gelatin. Modern soil pressure theories were mostly based on the " wedge theory " and included the friction effects in the earth face of a retaining wall or pile. To this extent, therefore, the experimental technique itself imposed conditions on the use of the method. However, the method gave an experimental basis for the solution of " elastic soil " problems, e.g., the influence of a surcharge load due to the approach of a wheel load to the wall could be studied visually by the use of photo-elastic apparatus of the type under discussion.

Mr. Noel W. Murray had been fortunate in being able to take up the author's work after the author had left the University of Adelaide and to apply the technique developed by him. He said Mr. Wilkins had mentioned the difficulty of using gelatin, which was an elastic medium, to study a problem in a soil which was not quite elastic, and he wished to add a few remarks in that field. Gelatin, used as a photo-elastic medium, was eminently suited to two classes of models. First, because of its high stress-optical sensitivity, it was suitable for studying structures in which the body stresses were a large percentage of the total stress, and second, because of its ease of casting, it was readily applicable to problems which involved two media. For the latter type of problem, Marco resin appeared to be the only other material available, but it presented a great number of practical difficulties. Other factors which allowed gelatin to hold a place of importance among photo-elastic materials were its cheapness, availability, relative freedom from time edge effects, and the control of its properties available to the operator by variation of mix proportions and working temperature. However, it was felt that for quantitative work the use of gelatin should be restricted to those problems which were essentially elastic in nature. Since soils did not entirely fulfil that condition, and also because they were either incapable of sustaining tensile stresses or failed under low tensile stresses, the results of such an investigation should be used with caution. It had been shown experimentally by Dr. P. W. Rowe* that the effective value of Young's modulus for sands was proportional to the depth below its surface. By using a gelatin model having a Young's modulus value which was constant throughout its depth, some adjustment of the quantitative results would be necessary.

During the investigation carried out in Adelaide it had been found that gelatin had a number of properties which affected the method of analysis. The gelatin used had been a refined eating gelatin, whereas that used by the author had been a commercial variety.

At high stresses gelatin exhibited a considerable amount of mechanical and optical creep. That creep could have a considerable influence upon the results. To a first approximation these effects could be reduced by allowing a standard time interval to elapse between loading the gelatin model and examining it. The same standard time interval should be allowed in calibrating the gelatin for fringe value and Young's modulus. Amongst temperature effects there was a variation of Young's modulus. Use of a material with a differential temperature coefficient, as the author pointed out, was an advantage, as it allowed a choice of model material. However, it was seen that this might necessitate the use of temperature control equipment. Piecemeal analysis of a large model usually took two to three hours, and in this time the heat generated by the body of the operator and light source could affect the temperature to a considerable degree. The accuracy of the photo-elastic analysis was determined by how close the colour of the stress pattern could be judged. When using gelatin, one usually found large areas of the model coloured between the yellow and black (isotropic) condition. Errors in $(p-q)$ values were more likely in this region than, say, between a yellow and orange fringe. These errors might accumulate on numerical integration, e.g. by the Frocht shear difference method. Probably the simplest way of overcoming this difficulty was by plotting curves of $(p-q)$ against location. Other means available were compensation (this was only possible in certain types of polariscopes) and relative rotation of the polarising components.

Mr. H. Fessler said that, although he had never tried the " sandwich " technique himself, it seemed to him to be no less difficult than the frozen stress attack. The sensitive slice required to be heated three times and to be machined repeatedly. After sticking together the model was machined and examined in an immersion tank. For frozen stress one must buy or cast a piece of material, machine it, freeze stresses into it, slice it and examine the slice. Neither was a quick or elegant method, and both seemed to call for patience and skill. Regarding the authors' claim that repeated readings gave more accurate results, he had looked at the beautiful straight lines in Fig. 4 and Fig. 5 of the paper and acquired far more confidence in the single points which one got from frozen stress slices. He estimated the maximum deviation of any point from those straight lines as 8 per cent. This seemed small compared with a maximum error of 18 per cent, due to the optical sensitivity of the Perspex.

Colonel H. T. Jessop said that the " sandwich " method described by Drs. Lamble and Bayoumi was valuable as another string to the stress analyst's bow. He did not see that either in simplicity or in accuracy the method was likely to replace the frozen stress or the scattered light method in general applicability, but there were quite possibly cases where it might be used when the special advantages of small deformation and small variation in Poisson's ratio from the value for a metal might be essential. With regard to the optical effect in the Perspex itself, Dr. Heywood had called attention to the estimation of the equivalent fringe value, and he was afraid that criticism was correct. The calculation on the basis of the uniform load certainly could not be applied to the case of a light beam passing through a model where the stress difference between the axial and circumferential stress would vary, so that the main stress through the Perspex layers would be widely different from the stress in the mid-Catalin layer. Actually a very accurate correction for the stress in the Perspex could be made for one particular region, and that was a region of intersection of two planes of symmetry, i.e. down the axis of the cylinder and across the diameter at the base of the notch, this being the important region. All one had to do was to machine a precisely similar model in solid Perspex and examine that under the same loading. The difference between the optical effect in the composite model and that in the Perspex model would be the difference between the optical effect through the Catalin slice and through a Perspex slice, and, knowing the relative fringe values, one could get a very accurate compensation for that region.

With regard to the difference in refractive indices between the medicinal paraffin and Perspex, the authors said that they were approaching the matter from the engineer's point of view and not from the physicist's point of view. Here he wanted to make a very strong representation that one was dealing with a physics problem, and that the engineer must learn his physics and use it. One could not apply the approximate principles of engineering to very delicate physical phenomena. When one was using a curved model and light was passing through the model, there were regions where the angle of incidence of the light approached 90 deg. When that happened the amount of refraction that occurred, even with an extremely small difference of refractive index, became very large. In this case, when the angle of incidence was 80 deg., a beam would be bent by 9 deg. on entering the model and another 9 deg. on exit. Towards the edge of a circular model that might make a very serious error in measurement. He had checked up the optical effect in the charts of the authors and there was no serious error due to that cause in this particular case, but there might very well be and one had to explore that possibility. With this difference of refractive indices, not only did one get large refraction on going from the lower to higher optical density, but when one went from the medium or greater optical density to that of less optical density, complete internal reflection would occur, in this case when the angle of incidence became about 76 deg. That was the explanation of the black fringe seen across the picture of the Perspex model unloaded. He concluded by again emphasising that photo-elasticity was a phenomenon concerned with physics. He was afraid there was too much of an impression getting abroad among engineers that photo-elasticity was a simple job and that all one needed to do was to look at a pattern and then one had the answer. Photo-elasticity was simple, but the investigator must be prepared to make an extremely careful analysis of what was happening optically and stress-optically in his model if he was going to avoid pitfalls and what one or two contributors had called spurious optical effects, which might make very serious errors in results.

Mr. P. J. Pollock said that Drs. Lamble and Bayoumi had certainly produced an ingenious method of determining three-dimensional stresses, but it appeared to require just as highly skilled a technique as the stress freezing process. It was rather surprising that the junction layer between the Perspex and Catalin did not cause interference. The advantage claimed for the method was that a number of loads could be applied to the same model. Did this mean any more than that, the material being elastic, one could reduce the range of probable error by taking a number of readings of the same set of stress ? But even in the stress freezing method one could take a number of slices reasonably close together and obtain a series of stress curves so that one did not have to rely entirely on one set of readings. Another limitation which was inherent in either method was that unless the section being examined was a principal plane, the stresses found would not be principal stresses.

Mr. W. M. Hickson said that Drs. Lamble and Bayoumi had had two problems to solve : to obtain a sensitive and a non-sensitive material with the same Young's modulus and to stick them together effectively without introducing residual stress.

* P. W. Rowe, " Anchored Sheet Pile Walls," *Journal I.C.E.*, Part I, Vol. 1, No. 1, 1952.

They had succeeded in those requirements by devices which would be of interest to plastics and adhesives chemists. There were certain factors which still remained to be adjusted. For example, the creep of Perspex was appreciably greater than that of Bakelite, which was stated to have about the same creep properties as the modified Catalin. He could find no reference to the equality or otherwise of Poisson's ratio for the two materials in the paper. It was conceivable that a relatively small difference in this property would cause undesirable shear stress on the cemented planes. A property to which Col. Jessop had drawn attention and which could give rise to experimental difficulty was the refractive index. The refractive index of Catalin was high—about 1·65—and of Perspex it was about 1·5. The technique appeared to be very well adapted to the determination of stresses due to transverse bending in plate structures. The requirement was to cement an insensitive sheet to a sensitive sheet and to treat the composite sheet as if it were a plane stress case. Since sheet thicknesses were equal and boundaries in the direction of viewing were straight, the residual optical sensitivity of Perspex would be unimportant and refractive index troubles would not arise.

The paper by Mr. Crisp on the use of gelatin models was particularly useful and interesting in that it gave a clear statement of similarity conditions when more than one material was involved, and that it demonstrated that these conditions could be fulfilled by adjusting the gelatin mix and the temperature of the model. The gelatin technique had a distinct advantage here over the alternative, which was the centrifugally loaded frozen stress model. In body force problems with a model constructed of a single material, he would favour the centrifugal loading, since it was not restricted to plane stress cases, lubrication difficulties did not arise, and he suspected that spurious edge stress was not so great. However, for the class of problem presented here, i.e. with a composite model of two materials of different moduli, the gelatin technique gave the necessary similarity conditions and supplied the required information, though he regretted that the author had not had the opportunity to include a specific problem with a comparison of photo-elastic results with observations on an actual bulkhead. The reader of the paper had very little opportunity of assessing the overall accuracy of the gelatin technique.

Mr. Benham asked whether the authors had considered or attempted to use Columbia Resin C.R.39, as the optically sensitive medium instead of Catalin? Although possessing the disadvantage of having a fringe value of roughly double that of Catalin, it had mechanical properties which generally appeared to be much closer to that of Perspex in value of Young's modulus, refractive index, Poisson's ratio, &c. It seemed to suffer less from time edging effects than Catalin and, having a highly polished surface, it was far more clear and transparent when constructing a joint. The composite model mentioned in the paper could be arranged to accommodate the standard $\frac{1}{16}$in or $\frac{1}{8}$in thick sheets. As far as the bonding side of the paper was concerned, he wondered whether perhaps a cold-setting bond could be used, such as Arondite 101, combined with the harder one, possibly to save time and some of the trouble involved in the initial heat treatment required when applying the first layer of Tensol to Catalin.

Mr. C. Snell drew attention to the fact that for problems of circular symmetry the stress difference in the boundary in the plane containing the axis was given by the scattered light method, and where, in addition, there was a plane of cross-section which was also a plane of symmetry, the scattered light method enabled one to obtain both principal stress differences from the same model. That was a distinct advantage over the sandwich technique and the preparation for such an experiment would be a good deal less than that of the sandwich technique; but, of course, the measurements would take a good deal longer and they would not have the same graphical representation which apparently had a general appeal.

The authors replied shortly and the meeting ended.

B.S.R.A Resistance Experiments on the "Lucy Ashton"*

By J. F. C. CONN, D.Sc.,† H. LACKENBY, M.Sc.,‡ and W. P. WALKER§

No. I

In this paper the results of the resistance trials in the "Lucy Ashton" are analysed to establish ship model correlation for the rated hull conditions. Test conditions and the work carried out to establish the roughness effect of several surface conditions are described, together with the wind tunnel tests. The resistance of the "Lucy Ashton" models are extrapolated on the basis of the Schoenherr, Telfer and Prandtl-Schlichting lines and the Froude method, and the predictions compared with the actual results.

The Ship-Model Correlation for the Naked Hull Conditions

Sir Maurice Denny's paper at the International Conference of Naval Architects and Marine Engineers, 1951, dealt with the details of the experimental equipment and the conduct of the ship trials of the "Lucy Ashton," carried out by the British Shipbuilding Research Association. The present paper is complementary and deals with the correlation of the measured ship resistance with the results of tests carried out on a series of geometrically similar models in an experiment tank. The scope of the present paper is restricted to ship model correlation on the basis of resistance for the four naked hull conditions of the ship as follows :—(i) Sharp seams with red oxide paint (normal service condition of the hull); (ii) faired seams with red oxide paint; (iii) sharp seams with bituminous aluminium paint; (iv) faired seams with aluminium paint (smoothest hull surface tested).

The paper gives details of the ship trial results and the corrections which had to be applied to them.

The paper is subdivided into three sections as follows :—A—The ship results and their correction to a standard condition; B—the measurement and analysis of hull surface roughness; C—the model results and their correlation with the full-scale ship resistance.

These are followed by the detailed summary and conclusions and the following appendices :—I—Tabulation of the Full-Scale Ship Results; II—Tabulation of the Model Results; III—The Correction of the Model Results for Tank Boundary Effects.

Section A.—The Ship Results and Their Correction to a Standard Condition

Details of the full-scale experimental observations are given, together with an account of the various corrections. These included reduction of the results to the following standard condition :—Correction to a standard water temperature of 59 deg. Fah. Elimination of wind and air resistance so as to obtain the water resistance only. Elimination of tide effects on speed measurement. Correction of resistance to a standard mean displacement of 390 tons. (The displacement varied slightly in the course of the trials owing to consumption of fuel.) Correction of resistance for the effects of rudder used during the mile runs.

Trials Data.—The Gareloch measured mile is divided into two half-mile sections by a pair of posts in the middle, and there is a further set of posts dividing the southern half into two quarters. The times for the first and second half miles and also for the full mile were taken and, in spite of the fact that the maximum length of approach run and diameter of turn that space permitted were used, there was often a slight increase in speed over the mile, especially at the lower speeds. For this reason the speeds have been based on the times for the second half mile as corresponding more closely to steady conditions. Having regard to the degree of accuracy with which the times could be measured with the cinetheodolite, the errors arising as a result of taking the times over the shorter measured distance are quite negligible.

Engine thrusts were read at half-minute intervals throughout the approach run and over the measured mile. The measured resistances are the sums of the four mean thrust-gauge readings over the mile, corrected in accordance with the gauge calibrations made on the day of the trial and with allowance for the inclination of the engine suspensions due to change in running trim. They therefore represent the actual resistance to motion encountered on the particular run, and corrections were made for displacement, temperature, rudder angles, and wind and air resistance, to obtain the thrust corresponding to the standard condition.

The changes in trim were occasioned by the hydrodynamic forces on the vessel under way and small trimming moments arising from the use of fuel. The change in trim for each run relative to the static condition before the trial was recorded.

The displacements are based on accurate draughts taken in still water and corrected for the weight of fuel on board.

Continuous records of rudder angles were

Nomenclature and Symbols

A = Cross-sectional area of water in experiment tank.
A_m = Midship section area.
A_T = Transverse projected area of the ship above the waterline.
A_w = Area of waterplane.
a = Mean cross-sectional area of model $= \frac{\nabla}{L}$.
B = Maximum breadth to mean thickness of shell.
b = Breadth of water surface in experiment tank.
C = Resistance coefficient $= \frac{R}{\frac{1}{2}\rho V^2 S}$.
C_f = Frictional resistance coefficient $= \frac{R_f}{\frac{1}{2}\rho V^2 S}$.
C_b = Block coefficient $= \frac{\nabla}{LBd}$.
C_m = Midship area coefficient $= \frac{A_m}{Bd}$.
C_p = Prismatic coefficient $= \frac{\nabla}{A_m L}$.
C_w = Waterplane area coefficient $= \frac{A_w}{LB}$.
d = Mean moulded draught to top of sagged keel.
e.h.p. = Effective horsepower.
g = Acceleration due to gravity.
k = Wind resistance coefficient $= \frac{R}{\frac{1}{2}\rho V_r^2 A_T}$.
k_s = Equivalent sand grain size.
L = Length of ship (*LBP*).
R = Resistance in general.
R_f = Frictional resistance.
R_r = Residuary resistance.
R_t = Total resistance.
R_n = Reynolds number $= \frac{VL}{\nu}$.
S = Wetted surface area.
$t°$ = Temperature of water.
V = Speed.
V_r = Relative wind speed.
v = Tank carriage speed.
Δ = Displacement.
∇ = Volume of displacement.
δh = Depression of water level in way of model due to backflow.
δv = Backflow velocity in way of model due to constriction.
ν = Coefficient of kinematic viscosity.
ρ = Specific density.
ϕ = Ratio of frictional resistance to total resistance $= \frac{R_f}{R_t}$.
© = R. E. Froude's resistance constant
$= \frac{125S}{\pi \nabla^{\frac{2}{3}}} C = \frac{2938R}{\Delta^{\frac{2}{3}} V^2} = 427 \cdot 1 \frac{\text{e.h.p.}}{\Delta^{\frac{2}{3}} V^3}$,
where R and Δ are in tons (salt water) and V is in knots.
AP = After perpendicular.
FP = Forward perpendicular.
ABP = Amidships between perpendiculars.

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*Institution of Naval Architects' Spring Meetings. Abstract.

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‡Principal Assistant Naval Architect, The British Shipbuilding Research Association.
§William Denny and Bros., Ltd.

taken throughout the runs and were remarkably steady.

The direction of the relative wind is expressed as the angle off the bow, port or starboard. When the wind speed varied during a run the mean relative wind speed for the run has been used.

Careful note was kept of the sea conditions throughout the trials.

The pitometer logs remained housed while the vessel was on the measured mile in order that they should not contribute to the resistance of the ship; but, whenever possible, No. 1 log was lowered at the end of the run while the engine settings and course were maintained, in order to obtain a measure of the water speed for use in tidal analyses.

Correction of the Results to a Standard Condition.—During the course of the trials the temperature of the water varied between 42 deg. and 57 deg. Fah., and all results were finally corrected to a standard temperature of 59 deg. Fah. by the following method.

The resistance of a ship is affected by the temperature of the water in two ways:—

(*a*) By variation of viscosity, which affects the skin frictional resistance only;

(*b*) By variation of density, which affects the total resistance.

The skin frictional resistance can be represented over a wide range of speed by a relation of the form

$$C_f=\frac{R_f}{\frac{1}{2}\rho V^2 S}=K\left(\frac{VL}{\nu}\right)^n \quad . \quad . \quad . \quad . \quad (1)$$

where R_f is the frictional resistance and K and n are constants, the other terms having the usual significance. If ρ and ν refer to the temperature at which the trials were carried out and ρ_1 and ν_1 to the standard temperature, then it can be shown that the corresponding relation for total resistance R_t is given by

$$\frac{\delta R_t}{R_t}=\frac{\rho_1-\rho}{\rho}+\phi\frac{\rho_1}{\rho}\left[\left(\frac{\nu}{\nu_1}\right)^n-1\right] \quad . \quad . \quad . \quad (2)$$

where ϕ is the ratio of skin frictional resistance to total resistance, i.e. R_f/R_t.

The value of n has been determined from Schoenherr's line to be $-0{\cdot}1308$ over the ship range.

Within the restricted ship range of temperature it was found that the variation of ρ and ν were very nearly linear, with the consequence that the above formula could be reduced to the simpler form

$$\frac{\delta R_t}{R_t}=\left(\frac{1}{\rho}\frac{d\rho}{dt^\circ}-\phi\frac{n}{\nu}\frac{d\nu}{dt^\circ}\right)\delta t^\circ \quad . \quad . \quad . \quad (3)$$

where δR_t is the change in resistance corresponding to a change in temperature of δt°, and ρ and ν are taken as mean values over the range. Values of ρ, ν and the gradients $d\rho/dt^\circ$ and $d\nu/dt^\circ$ were taken from Lyle and Hosking's tables and were confirmed by actual measurements of viscosity made on samples of the Gareloch water. On substitution of the appropriate values, equation (3) reduces to the form

$$\frac{\delta R_t}{R_t}=\frac{(t^\circ-59)}{1000}[0{\cdot}0916+1{\cdot}948\,\phi] \quad . \quad . \quad (4)$$

where t° is the temperature in degrees Fahrenheit at the time of the trial. This gives the necessary correction to bring the results to the standard temperature of 59 deg. Fah. and has been used in analysing the ship results. Equation (4) applies only to the range of Reynolds numbers covered by the "Lucy Ashton" trials and to the restricted range of temperature of water encountered.

This temperature correction was relatively very small and varied from a maximum of 3½ per cent at low speeds to about 1½ per cent at high speeds.

In determining ϕ, the ratio of skin frictional to total resistance, Froude's skin frictional coefficients were used.

Many attempts were made to obtain a reliable value for the wind resistance of the ship in natural winds of various velocities. The method adopted was to moor the vessel to a buoy and to measure the pull due to the wind in the mooring rope, the force in the rope being transmitted through a bridle to a Macklow-Smith load-measuring capsule secured to the bow of the ship. Synchronised readings of wind speed and direction, pull on the bridle, and the obliquity, both vertical and horizontal, of the mooring wire were taken every ten seconds, and the speed of the tide past the vessel was estimated.

Gauge readings showed considerable fluctuations due to cyclic variations in the wind speed. However, a mean figure for the pull in the wire, corrected for obliquity of the mooring wire, gave a fairly reliable value for the resistance due to a wind blowing from directly ahead.

To determine the correction due to relative winds at various angles on the bow it was decided to carry out wind tunnel tests. The model was constructed in wood to a scale of 1/24. It represented only the above-water portion of the ship and was cut off flat at the water line. The model was simplified in certain respects, for the purpose of these tests; small items were omitted, but guard rails and stanchions were added, as these might affect the eddies from the deck edges.

The model was slung from the roof balance in the tunnel in an inverted position, and the flat bottom representing the water plane was brought just clear of a horizontal board or "artificial sea" spanning the tunnel. The measured resistance corresponded to that of the above-water form only, and was taken over a range of angles of relative wind. The tests were carried out at a nominal tunnel wind speed of 62·5ft per second, and measurements were taken at positions corresponding to those at which the wind speed was actually measured on the ship. Velocity traverses made through the boundary layer adjacent to the "artificial sea" showed that this did not extend more than about 4ft above sea level on the full scale. Therefore the positions at which the wind speed were measured on the ship were clear of the effect of the boundary layer.

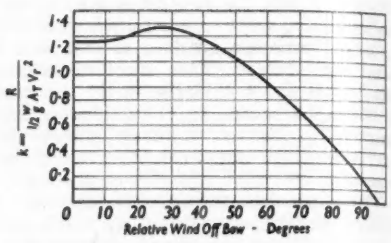


Fig. 2—Curve of Wind Resistance Coefficient

The results of the wind tunnel tests are summarised in Fig. 2 in the form of a resistance coefficient plotted on a base of angle of wind on the bow. The resistance coefficient is expressed as

$$k=\frac{R}{\frac{1}{2}\rho V_r^2 A_T}$$

where

R = the fore and aft component of the wind resistance (lb).

ρ = specific density of the air (lb-sec² ft⁻⁴).

V_r = the relative wind speed at a given angle on the bow (ft per sec).

A_T = the transverse projected area of the ship above the water line, that is the frontal area projected on to a plane at right angles to the ship's length (419 square feet).

The average horizontal component of the pull in the mooring rope measured at the ship was 316 lb, corresponding to a mean wind speed of 12·4 knots, and the corresponding head wind coefficient is 1·36, which compares with 1·25 as determined from the wind tunnel tests for zero angle off the bow. In analysing the ship results the curve given in Fig. 2 was used to determine the combined wind and air resistance; this was deducted from the measured results, thus reducing them to water resistance only.

At low ship speeds this correction generally varied between 10 and 20 per cent of the measured ship resistance and reduced to about 5 per cent at high speeds. In view of the high correction at low speeds, the opportunity was always taken, where possible, to make these runs when there was little or no natural wind, a speed under 10 knots being regarded as the upper acceptable limit.

A tidal analysis was carried out for some of the trials and showed that the tide was no greater than 0·2 to 0·3 knot, so that corrected water speeds determined from the tide curves were almost identical with those determined by taking the mean of two runs with and against the tide.

The displacement varied owing to the consumption of fuel, and it was necessary to correct the resistance accordingly to a standard displacement. The total fuel carried was about 12 tons, and it was decided to reduce all results to the "half-tank" condition of 6 tons, which corresponded to a displacement of 390 tons. The correction in pounds resistance per ton change in displacement at various speeds was determined from model tests and was generally less

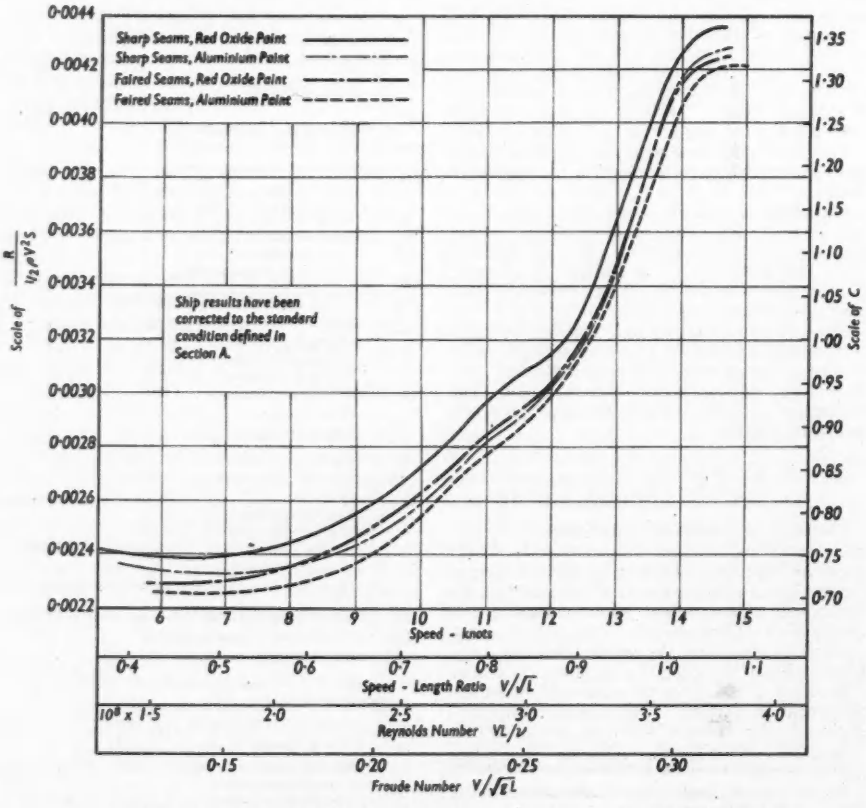


Fig. 1—Comparison of Full-Scale Resistance Coefficients for the Four Naked-Hull Conditions

than 1 per cent and at low speeds was altogether negligible.

A continuous record of rudder movements was obtained on a base of time ; the rudder angles were generally very small, the steady angle over any run seldom exceeding 3 deg. Nevertheless, the mean additional drag due to the rudder movements was estimated for every run and deducted from the measured resistance, although amounting to only a fraction of 1 per cent.

(To be continued)

The Erection of a Railway Bridge

We learn that a new railway bridge crossing the River Severn near Gloucester has been almost completely constructed. The bridge carries a double-track line, and is situated at Over Junction on the main line from Gloucester to South Wales, crossing the western channel of the Severn at a point immediately downstream of the old bridge built by Brunel. It consists of three 71ft mild steel, right-hand skew girder spans over the waterway, and one 15ft reinforced concrete span at each end. The main spans were erected with a single standard 45-ton breakdown crane.

The longer spans are of through construction, each with two main girders 81ft long spaced at 25ft centres. Cross girders carrying a solid concrete deck are supported on precast reinforced concrete jack arch units, resting on concrete skewbacks, the skewbacks being cast on the bottom flanges of the cross girders.

The alignment of the bridge is close to the existing railway tracks at the Gloucester end and diverges away from them at the right bank of the river. Although the girders for the span near the Gloucester end could be lifted directly off wagons standing on the down line on the old bridge, the distance between the old and the new bridges was too great for this procedure to be adopted for erecting the girders for the other two spans.

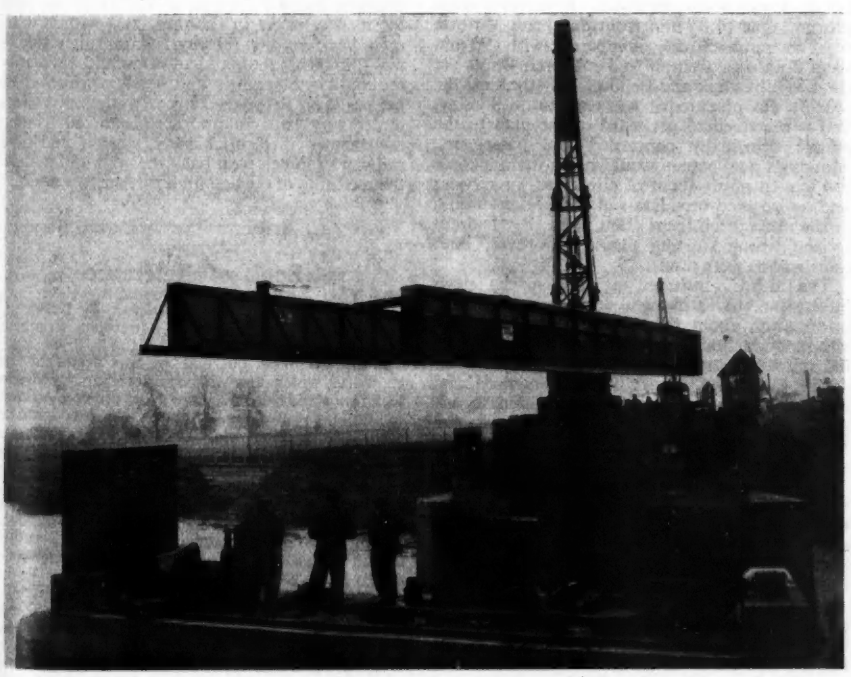
Erection of the girders started from the west end of the bridge on November 25th, when the main girders for the first span were set in position on their knuckle bearings. Each girder weighed 35 tons, and the first to be launched, the downstream one, was fitted with an extension nose girder weighing some 2½ tons, which increased its length to 108ft. Tracks were laid over the approach and a 45-ton breakdown crane, standing on the down track at the end of the reinforced concrete approach span, lifted the girder off its wagons on the up track and swung it out over the water until the nose girder landed on rollers mounted on a ball-bearing turntable on the far pier. Our illustration clearly shows this operation in progress ; the nose girder and the turntable on the pier in the foreground may be noted.

The load of 35½ tons was beyond the capacity of the crane, when working at the radius that would have been necessary to handle the girder, in a single lift, into its final position. However, with the nose girder on the pier, and the main girder supported some 25ft from its other end on the approach span, the lifting " nips " were moved further along the girder before another lift was made by the crane, and the girder was launched forward on the rollers under the nose girder. This process was repeated until the whole of the nose girder projected beyond the pier and the main girder spanned the opening, square to the piers. A final lift at the " tail " enabled the girder to be swung round and lowered on to the knuckle bearing at that end. At the far end, jacks lifted the girder clear of the turntable, which was withdrawn and the girder was lowered on to its bearing. The upstream girder was launched in a similar manner, though in this instance it had to be worked across the opening on the skew, necessitating the use of a 36ft 6in long nosing girder weighing 3 tons, giving a combined length of 117ft 6in.

The nosing girders were bolted to the ends of the main girders and were fitted with a framework of steel channels level and parallel with the bottom flanges, to increase the width of the temporary bearing on the turntable. Banjo wires strained over a steel joist set at right angles to the girders ensured that they were held in line during the launching.

On completing the erection of the cross girders of the first span, temporary tracks were laid across that span and with the crane standing on the far end the girders for the second or middle span were launched in the same way on January 15th. The girders for the third span were unloaded from wagons standing on the down line on the old bridge, and were handled with two cranes, one standing on the second new span and the other on the concrete span at the Gloucester end of the bridge.

The launching of the 81ft girders of the first two spans with a single crane having a capacity for handling a 45-ton load at a radius of only 20ft was, of course, only possible through the use of a nosing girder, but their installation was remarkable on account of the very small quantity of special equipment required, namely, the nosing girders and the turntable. The supply and erection of the steelwork was carried out by the Fairfield Shipbuilding and Engineering Company, Ltd. The erection scheme was worked out by Mr. C. R. Shackle, the resident engineer, and was carried out under the instructions of Mr. M. G. R. Smith, the civil engineer of the Western Region of British Railways.



Lifting Bridge Girder into Position

Induction Stirrers for Electric Arc Furnaces

Last Friday we attended a film and a lecture on induction stirrers for electric arc furnaces, given in London by Dr. P. E. Hammerlund, manager of the Furnace Department of A.S.E.A., Sweden. As stated in the lecture, the induction stirrer originated in 1936, when Dr. Dreyfus studied the problem of electro-dynamic means of producing a stirring effect in a hot metal mixer. The principle of stirring by electromagnetic induction was first applied on a commercial scale to a 15-ton electric arc furnace in 1939, and it has since been adopted on a number of installations in various parts of the world.

The induction stirrer evolved by Dr. Dreyfus and manufactured by A.S.E.A., consists of a two-phase, low-frequency winding, installed immediately below the furnace bottom, which must be non-magnetic. A travelling electromagnetic field is produced by the low-frequency currents in this winding and the effect of this moving field is to produce a corresponding movement in the bottom layers of the melt, with a return movement near the surface. The principle is akin to that of the induction motor.

The magnetic yoke of the stirrer is built up of steel sheets, say 1in thick, slotted to carry the heavy current conductors forming the winding. Cooling is by air blast or, more usually, by using hollow, water-cooled conductors. Usually the stirrers are suspended directly from the furnace bottom, with a space of 1in between the bottom of the furnace and the upper surface of the stirrer. The low-frequency currents in the stirrer are produced by a motor generator set consisting either of two single-phase generators or of a two-phase generator driven by an induction motor. A stirrer for a 30-ton arc furnace (16ft inner shell diameter) would have a total power consumption, including that of the cooling equipment and exciter of about 180kW, of which about 115kW at a power factor of 0·5 would be taken by the stirrer itself.

The advantages of the induction stirrer include a saving of time, resulting from the stirring action, mainly in the refining period ; an improvement in the quality of the steel, quick homogeneity of the melt and a speedier approach to equilibrium conditions. Stirring also facilitates reliable analysis and rapid sampling and it introduces greatly improved deslagging conditions and reliable temperature control.

The properties of temperature equalisation, homogeneous analysis and ease of deslagging were paramount considerations in a recent order involving an induction stirrer for a 150-ton arc furnace with an inner shell diameter of 24ft, which, we understand, will be used mainly for producing ordinary carbon steel.

Exhibition of Electrical Engineering

The second electrical engineering exhibition organised by the Association of Supervising Electrical Engineers is being held at Earls Court this week. The exhibition was officially opened at noon on Wednesday last by Sir John Hacking, deputy chairman of the British Electricity Authority, and is remaining open daily from 10 a.m. to 7 p.m. until to-morrow, Saturday. This event is the outcome of a small electrical exhibition which was staged by a branch of the Association of Supervising Electrical Engineers three years ago. Last year the Association organised the exhibition on a national scale and it was held at the Horticultural Hall, with fifty-eight exhibitors. This year there are nearly twice as many exhibitors. The central theme of the exhibition is the application of electricity to illumination with the help of " Illumination Way," a 200ft display of electric lighting fittings contributed by various manufacturers. A subsidiary theme is commercial cooking, and on the industrial side manufacturers of motors, transformers, control and protective gear, instruments and wiring systems are well represented.

Emergency Flood Works on the Eastern Region of British Railways

AT a recent Press conference held by the Eastern Region of the Railway Executive, some details were given of the emergency measures taken to combat the floods caused in East Coast areas by the exceptional tide on the night of January 31st last. Prompt action was called for by those responsible for the operating, motive power and civil engineering departments, to minimise the damage caused by the floods and the consequent interference with services. It was also pointed out that particular credit is due to the initiative shown by railway employees in places directly affected by the catastrophe. Of the many incidents which took place on the Eastern Region lines during the flooding, we give below examples, which may be taken as typical of others as well, of the emergency work.

By 6 a.m. on the Sunday morning 145 miles of railway were flooded or cut off. Providentially, only one operating railwayman lost his life although there were many narrow escapes. The water supplies at several of the motive power depots near the East Coast which were affected by the flooding were contaminated by the salt water and the immediate application of "Polyamide" was successful in reducing priming to a minimum. A quantity of silver nitrate was distributed to all coastal depots in this area to be used for testing for the presence of salt in the water.

The principal problems facing the operating administration on February 1st were, first, to plan and issue revised passenger train schedules for the Monday; secondly, to anticipate the demand, which was sure to come, for extra supplies of coal and relief goods for the stricken areas; thirdly, to sort out the traffic which could be handled from the traffic which could not (principally in the places where a large industrial area was under water); fourthly, to make ready for the several thousand wagons of spoil, slag and materials for repair work.

There was one factor of crucial importance which governed the considerations for the next twenty-four hours. It was that at the coastal depots which were either flooded or cut off by floods there were impounded over 600 coaches and over 100 engines. The worst case was Shoeburyness, where there were 326 coaches and thirty-five engines fitted with automatic train control; this stock could not be substituted by borrowing from elsewhere. With very little reduction in passenger travel to be expected and with very greatly increased movement of freight it was obviously of vital importance to get engines and stock out of the flooded area as quickly as possible, and for this reason some risks were taken over track which would normally be regarded as unsound.

For Monday's work, however, the planning teams were over 600 coaches and 100 engines short. It is not possible to follow the considerations which governed all the replanning which took place on the Sunday so the service from Southend to London is given as an example. The line was cut in three places—between Leigh and Benfleet, between Stanford-le-Hope and Tilbury, and between Grays and Purfleet. Of some 45,000 people using Fenchurch Street Station each day about 10,000 travel up in the morning from Southend and return in the evening. Of these passengers, a little less than 8000 travel from the stations cut off between Leigh Shoeburyness.

The capacity of Plaistow motive power depot, with the few engines remaining in it after the general movement to the coast on the Saturday had been completed, was assessed at four trains an hour from Benfleet to London. Coaching stock available at the London end could match these engines with trains of eight coaches only and that only after fifty-six had been got through the flood from Tilbury on Sunday afternoon. It appeared obvious that Benfleet could therefore deal with only its own traffic plus the people who required to travel from Southend to stations intermediate between Benfleet and Bromley (who would be brought by train to Leigh and thence by bus to Benfleet), plus again the normal traffic joining at stations between Pitsea and Upminster.

There remained the 8000 passengers to be brought by some means from the Southend Borough to London. The old Great Eastern terminal at Southend Victoria had reserve capacity. There were sufficient engines available at Stratford, but only three trains of high-capacity suburban coaching stock could be found.

The movements of these 8000 people, even assuming some overcrowding in the booked Southend Victoria/Liverpool Street service would require three trains an hour for which the coaching stock available could only do a comparatively short journey. It was decided, therefore, to run the steam trains from Southend Victoria only as far as Shenfield where they would turn back and make another trip as quickly as possible. Forward from Shenfield, since there was no steam stock, electric trains must run. Of these trains, one could be given up by the electrical department out of maintenance for a few days and three would have to come from the normal Liverpool Street service. It was understood that there would be considerable overcrowding which would have to be faced.

The next question was whether to use Liverpool Street or Fenchurch Street as the terminal, and the choice fell on Fenchurch Street. This choice was made, first, in order to get the people to their usual terminal; secondly, to relieve Liverpool Street of the platforming difficulties which would ensue, and thirdly, to offer from Fenchurch Street in the evening the possibility of an alternative service to Southend which would avoid the Benfleet trains leaving off large numbers of people in the down direction.

Having decided on Fenchurch Street the administration had to make the line fit for electric trains between Bow Junction and Fenchurch Street, where, owing to disuse, the contact wire was heavily sooted. To do this a "ghost train" ran three trips during the Sunday night, and in fact no mechanical trouble was experienced from contact wire conditions.

The operational plan was prepared in detail and typed during the Sunday afternoon and copies distributed to the key stations, motive power depots and supervisors. It provided for a journey time of 77 min from Southend Victoria to Fenchurch Street, compared with 90 min from Southend Central to Fenchurch Street via the Leigh bus link and Benfleet. By the time the scheme was prepared it was teatime on Sunday, and it remained to get word of the plan to the people principally concerned—the passengers. Monday's newspapers would reach many people too late to notify them of alterations in services and notices and broadcasts at the stations would in the main reach them often when they had got to the wrong starting place. However, both these means were used.

The B.B.C. included a note in its news bulletins, but although it broadcast some information about the Southern Region, it did not mention Southend. Notices were given in the Sunday cinemas; the chairman and secretary of the Travellers' Association were advised, and finally, the bus company was requested to ask its conductors on all routes to broadcast that Southend Victoria, and not Central, was the station London travellers should use.

On the Monday morning things did not go at all well—the trains ran and ran well to time, but they were virtually empty. Some 1100 extra people travelled in fourteen trains from Southend Victoria, whereas the four trains an hour from Benfleet were very overcrowded.

There was some consternation in administrative circles and steps were initiated to adjust the traffic. That evening there was added to the barriers at Fenchurch Street a barrier separating the Shenfield from the Benfleet passengers. This combined with printed broadcasts, improved conditions and several of the Shenfield electrics left full and with standing passengers. With a good run that night the people spread the news quickly and within two days 8000 extra passengers were using the Shenfield route each peak.

A typical example of civil engineering work carried out by the Eastern Region staff arose opposite Canvey Island, where the Fenchurch Street to Southend line runs from Benfleet to Leigh-on-Sea. Over a length of some 3 miles, twenty-three breaches were forced in the river bank and the track was flooded to a depth of 8ft. For a few days, nothing could be done except to explore the area on foot and by boat whilst the impounded water poured back to the sea at end of low tide. At this stage, it was impossible to reconnoitre the major breach in detail, but arrangements were made to bring filling by barge, since the railway line was ¼ mile away across flooded marshland and no road access existed within ½ mile. With the approach of neap tides, flooding at each high tide ceased. It was then found that, as the result of scour, the major breach did not simply comprise a break, but a deeply scoured hole as well. It was immediately appreciated that the task of restoring the wall before the next spring tides was impossible and a decision made to build a temporary wall round the crater. In the meantime, strenuous efforts had been made to restore one track to a state that would allow of moving rolling stock from the main depot at Shoeburyness to the London side of the flood, thereby improving the service as mentioned above. By the Friday, five days after the flood, single-line working for passenger trains was reintroduced, on the understanding that it might have to be suspended again as the spring tides approached. In the meantime, mechanical plant and sandbags were moved to the breach and a start was made in the construction of the temporary sandbag-faced earth wall.

Once again, nature took an unkind turn and snow and sleet quickly turned the marsh into a quagmire in which even bulldozers bogged down. There followed a week of filling and placing sandbags. At midnight on Tuesday, February 10th, with only five days to the peak spring tides of the year, the wind raised the high tide by a matter of some 1ft 6in above normal, overtopped the lowest part of the temporary wall by a matter of some 3in and swept away a stretch of wall 30ft wide and ten sandbags thick. Once more the marsh was flooded, but not, of course, to the original depth. During the next day, men accumulated filled sandbags on each side of the gap and, at slack water, embarked upon the apparently forlorn hope of beating the rising tide. Half an hour before high tide, the resident engineer deemed the risk to life to be too great for men working in the dark and withdrew the man back to the railway. After high tide, it was found that the wall had stood and, thereafter, the wall rose steadily and safely withstood the peak tide on February 18th. By strenuous efforts under very bad conditions, this mixed team of contractors' men, bricklayers, welders and other railway shopmen won back the wall and avoided the reclosing of the line for a further two weeks.

Book of Reference

Waterworks Byelaws and Fittings. By Delwyn G. Davies. London: Colliery Guardian Company, Ltd., 30/31, Furnival Street, E.C.4. Price 30s.—The author points out that by-laws establish legal standards which tend to be lower than the desired technical standards. He thinks that much more could be done to promote a more frequent voluntary adoption of better standards by a scientific, but critical, appreciation of the requirements of by-laws. The present volume is an implementation of that view, in part by criticism of existing by-laws and fittings. A historical survey of by-laws and fittings is given with appropriate descriptions of contemporary apparatus and regulations, including, of course, British Standards, and aspects such as model codes of by-laws, difficulties of enforcement, the testing of fittings and so on. Whilst the descriptions of by-laws and fittings will doubtless be of use to water engineers, as will the author's comments upon them, the historical chapter and the general critical survey which are given go beyond the usual scope of a work of reference, and may be read with interest by engineers concerned with this subject.

Silicone Resins in Insulation at Power Frequencies*

By W. J. RENWICK, A.M.I.E.E., and J. R. REED, B.Sc. (Eng.)†

The authors examine the properties and behaviour of some silicone materials that are of interest to power engineers. Test methods based on British Standards are used, where possible, to simplify comparison with conventional insulating materials. With such tests, and accelerated life tests on motors using silicone resins as bonding and impregnating media, the authors show that these materials are capable of working at temperatures at least 50 deg. Cent. higher than those permissible for conventional insulants.

THE silicone resins, elastomers and fluids of importance as insulants are organic compounds of silicon, having a structure of alternate atoms of silicon and oxygen with organic groups such as methyl and phenyl attached to the silicon atoms. Since silicon is tetravalent, like carbon, a range of analogues to the conventional organic materials can be produced, but the silicon-oxygen bond imparts to the silicones a greater temperature stability than does the carbon-carbon bond to the organic compounds.‡

The chemistry of silicones, which has been described by Rochow,[1] forms one branch of organo-silicon chemistry, the fundamentals of whose systematic study were laid by Professor Kipping, of Nottingham University, between 1899 and 1944. However, the resins, elastomers and fluids now used as insulants were first produced on a commercial scale in 1944 by one American company, and somewhat later by another; some such materials are now being produced under licence in the United Kingdom.

Examination of silicone materials and of apparatus incorporating them as insulants has led to the introduction in the United States of a new class of insulation, designated[2] class "H." Briefly, this consists of silicone resins in conjunction with mica, asbestos or glass-fibre insulation, and silicone elastomers. The American Institution of Electrical Engineers has tentatively limited the maximum permissible "hottest spot" operating temperature for this class to 180 deg. Cent., while the United States Navy specifications permit operation at 200 deg. Cent.

The materials examined for the purposes of the paper have been some of those of interest to manufacturers and users of electrical power equipment. Some materials therefore have been tested only in built-up form, i.e. in conjunction with other materials. Moreover, no attempt has been made to measure the intrinsic or fundamental properties of silicones; rather, established British Standard test methods, or simple modifications of them, have been used to compare some of their characteristics and the manner in which these change with accelerated ageing.§ with those of conventional insulants. The tests have been in no way exhaustive, but it is hoped that the results, together with the experience gained during limited works application and the description of life tests on class "H" insulated motors, will both prove of interest and serve as a useful basis for progress.

Silicone Resins Bonded with Mica, Glass and Asbestos

Silicone resins enable greater advantage to be taken of the heat-resistant properties of mica, glass-fibre insulation and asbestos than other bonds when the bond also has to resist the ingress of moisture.

Silicone-Bonded Mica Products.—Built-up mica products bonded with silicone resins can be produced in forms similar to those bonded with organic resins, except that all cellulose backing materials should be replaced by woven glass fabric or, in some cases, by asbestos papers. Their electrical behaviour is determined mainly by the mica and is therefore similar to that of organic bonded materials.

Sheets of flexible mica-glass combinations can be prepared using the impregnating varnishes, generally with reduced solid content; where extra flexibility is required, the varnishes produced primarily for coating glass fabric should be used. Except when the sheets are to be cut into tapes, the resin is only partially cured, the curing being completed after application. Residual tackiness can be reduced by dusting with finely powdered mica or by adding to the impregnating varnish a bonding resin which dries tack-free in air. This mixture is preferable to either the solventless or emulsified resins available for the purpose.

Rigid mica products, such as commutator segments and washers, can be made using the bonding resins, as can heat-formable sheets for commutator V-rings using the resins developed for this purpose.

Silicone-Bonded Glass-Fabric Boards.—The method of manufacture of glass-fabric boards has been described in detail by Hyde,[3, 4] who has also compared the properties of ¼in glass laminates bonded with phenolic and melamine resins with those bonded with silicone resin. British Standard methods were used, where such exist, and his results are reproduced as Table I.

TABLE I.—*General Properties of Glass Laminates*

Property	Phenolic bond	Melamine bond	Silicone bond
Power factor at 1 Mc/s	0·06	0·08	0·002
Electric strength, V/mil	150–200	150–200	250–300
Breakdown along laminæ, kV/in	15–20	10–15	50
Dry insulation resistance, megohms	10,000	20,000	500,000
Insulation resistance after immersion in water, megohms	10	10	10,000
Water absorption, mg	40	20	5–10
Tensile strength, lb/sq in	$20–25\times10^3$	$20–25\times10^3$	$15–20\times10^3$
Shear strength, lb/sq in	$20–25\times10^3$	15,000	14,000
Impact test, flat, ft-lb	5·0	6·3	5·6
Impact test, edge, ft-lb	2·0	1·8	2·0
Effective temperature resistance, deg. Cent.	150	150	250

The characteristics of the silicone-bonded material are maintained to a very large extent after ageing for six weeks in air at 250 deg. Cent.; the tensile and crushing strengths depreciate only 25 per cent and 10 per cent respectively, and the breakdown strength along the laminæ remains greater than 50kV/in.

The E.R.A. have found that, while the silicone-bonded boards pass the carbon arc test of B.S. 737 : 1937, they ignite in the flame of a Barthel burner but extinguish on removal from the flame. The results obtained in the tests on ¼in thick boards are compared in Table II with those obtained on similar boards employing phenolic and melamine bonds.

TABLE II.—*Inflammability of Bonded Glass and Asbestos Boards (by the Methods of B.S. 737)*

Material	Nature of test: Deepest groove on fuse wire test	Nature of test: Penetration time of carbon arc	Nature of test: Time of burning after removal from flame of Barthel burner
	in	sec	sec
Silicone-bonded glass fabric	0·026	36*	6
Phenolic-bonded glass fabric	Material destroyed	20†	29
Melamine-bonded glass fabric	0·024	260*	4
Silicone - resin - bonded asbestos	0·056	195,* 240,* 280*	13
Silicate-bonded asbestos	0·033	130,* 184,* 260*	0*

* Complies with the requirements of B.S. 737.
† Material burned so freely as to affect the stability of the arc.

Silicone-bonded glass-fabric boards dry out quickly at room temperature from the wet condition and attain a high insulation resistance. Thus, the E.R.A. have shown that the insulation resistance between 2-B.A. screws 1¼in apart rises to greater than 10^{11} ohms in twenty-four hours' recovery after six hours at −40 deg. Cent. following twenty-one tropical cycles to Inter-Service Specification RCS/11.

Silicone-Bonded Asbestos Boards.—Asbestos for boards may be used in any of the usual forms, i.e. woven cloth, felt or paper laminate. The crosswise breaking strength, as determined by the three-point loading test of B.S. 972 : 1941, has varied between 830 lb per square inch and 25,000 lb per square inch for different boards, but there was no correlation with the form in which the asbestos was used. On some samples the crosswise breaking and crushing strengths have remained unaltered after ageing for six weeks in air at 250 deg. Cent.

Silicone-asbestos boards are produced which are self-extinguishing according to B.S. 737, and results on one such board are included in Table II, together with results obtained on a conventional board with a silicate bond.

Varnish Glass Fabric.—The electrical behaviour of commercial silicone-varnished glass cloth is very similar to that found when testing the impregnating varnishes, i.e. the electric strength at 20 deg. Cent. decreases by approximately 25 per cent when aged for one month at 220 deg. Cent. In the same time the tearing strength, as measured on the Marx-Elmendorf type of apparatus, decreased by 50–55 per cent. These figures compare favourably with those obtained when glass cloth coated with conventional varnishes is aged at 170 deg. Cent.

Silicone-varnished glass-fabric tapes suffer from the same disadvantage as those coated with organic varnishes, in that bias-cut tape must be used in order to provide sufficient extensibility to permit neat application. Unless great care is taken, this tape may be stretched to such an extent that the varnish film is destroyed. Similarly, in sheet form the material fractures when sharply creased, as may occur in some applications. While these disadvantages can be overcome by using Terylene fabric as the base cloth for organic varnishes, its use with silicone resins would appear to be doubtful when great heat stability is required.

Wire Coverings.—For some years the silicone impregnating varnishes have been used for coating glass-covered conductors. Their main disadvantage has been that the adhesion of the glass to the copper is weak compared to that obtained with organic varnishes. Nevertheless, with care they could be used satisfactorily. The first silicone varnish to be modified specifically to give good adhesion was thermoplastic and had relatively poor heat resistance. The latter has been improved in subsequent varnishes, but it is still not so good as that of the impregnating varnishes.

No success appears to have been obtained with silicone resins as wire enamels. Some of those produced, while possessing good electrical and heat ageing properties, have offered only poor resistance to abrasion and have been softened by even mild solvents. Modified resins appear to have failed on the counts of plastic flow, heat shock and thermal endurance.

Tests on Motors Employing Silicone-Resin Bonds and Impregnants

Since the effect of temperature is not the sole factor affecting the life of insulation in a machine, it was considered desirable to investigate the behaviour of the silicone resins under working conditions at high temperature. Accordingly, three standard three-phase squirrel-cage induction motors, rated at 1 h.p. output at 400V, 50 c/s, with class "A" insulation, were insulated in glass, mica and silicone resins as described in the Appendix. The only organic material used was the dextrin bond with china clay for the core-plate insulation. Thermo-couples were incorporated for temperature measurement, as described in the Appendix.

All three motors were directly coupled to d.c. generators which were loaded by resistance banks. The characteristics of output and efficiency with temperature are given in the diagrams. The motors were run during the day, followed by cooling overnight, the windings being within 10 per cent of their final temperature for eight hours each day. Motor A was built for miscellaneous rigorous testing and failed after about 5000 hours' operation; motors B and C

* Abstracted from a paper read at a Symposium on Insulating Materials. The Institution of Electrical Engineers, London, March 16–18, 1953.

† Witton Laboratories of the General Electric Company, Ltd.

‡ Wherever reference is made to organic materials, conventional materials, excluding fluorinated compounds, are meant.

§ A rough but useful guide for interpreting the rate at which deterioration is likely to occur in service from tests made after accelerated ageing is given in the Appendix.

have run under controlled conditions and were still running after 2250 and 1600 hours' operation respectively.

Miscellaneous Tests on Motor A.—Motor A was run at a slot temperature which varied between 250 deg. and 320 deg. Cent., with an average of 280 deg. Cent. and was periodically, subjected to atmospheres of high humidity at various temperatures or to immersion in water. The following examples, some of which have already been described briefly by Robinson,[5] are typical and serve to show how the water resistance of silicone insulation is maintained after ageing.

After 500 hours' running the motor was subjected to five "tropical" cycles, each consisting of eight hours at 60 deg. Cent., 98 per cent relative humidity, followed by sixteen hours' cooling to room temperature in the chamber. The insulation resistance at 500V d.c. of the winding to the core is shown here.

Number of cycles	Insulation resistance megohms
1	80
2	70
3	30
5	20

The motor was allowed to dry, and after a total of 1000 hours' running was subjected for forty-eight hours to an atmosphere of 95–100 per cent relative humidity at laboratory temperature. The insulation resistance fell only to 100 megohms.

After 1500 hours the motor was immersed in a 10 per cent salt solution for twenty-four hours and the insulation resistance fell to 300 ohms. However, after it had been washed in tap water, natural drying caused the motor to regain a high insulation resistance, as shown by the following results.

Time, days	Insulation resistance, megohms
1	1·3
2	30
4	>100

The loading was then reduced so that the winding temperature was between 240 deg. and 260 deg. Cent. and the daily runs were continued until, after approximately 5000 hours' running, the motor failed because an open circuit developed in the end winding. Oxidation of the copper conductors had evidently caused a local increase in resistance and hence in temperature until fusion occurred. Similar faults have been recorded by Grant and his colleagues.[6]

On examination, the varnish coating of the end windings was found to be crazed. Most of the conductor coverings were completely white and while there was a small amount of resin bonding the conductors in the slot portions, there was none in the end windings. There was considerable adhesion between the glass and copper of the conductors in the slot portions, but relatively little in the end windings. Surface oxidation of the copper was general throughout the winding, but was particularly pronounced in the end windings.

Controlled Tests on Motors B and C.—Motors B and C have been run under controlled conditions, and typical temperatures, measured by the embedded thermo-couples, are given in Table III.

TABLE III.—*Temperature Distribution*

Position	Temperature, deg. Cent.
Ambient air	20
End winding, driving end	246
Slot, driving end	244
Slot, middle	234
Slot, opposite driving end	260
End winding, opposite driving end	252
Stator tooth	234
Average winding temperature, by resistance	235

At intervals of approximately 300 hours running the motors were dismantled and the stators subjected to an atmosphere of 95–100 per cent relative humidity at normal temperature for forty-eight hours prior to the measurement of the insulation resistances between windings and stator iron. After motor C had run for 1600 hours the insulation resistance was still increasing. The windings appeared to be in excellent condition after motor B had run for a total of 2250 hours; the insulation resistance had not fallen below previous values with exposure of the winding to damp conditions.

After 2000 hours the stator iron losses in motor B showed no significant change, and it can be concluded that a mineral filler in an organic bond forms a satisfactory core plate insulant.

These machines will be run until such time as falling insulation resistance with exposure to damp conditions, together with increasing ohmic resistance of the windings indicate that oxidation of the copper has set in.

General Fields of Application

It is anticipated that the vast majority of commercial insulation will continue to be classes "A" or "B," or modifications of these which the advent, during the past sixteen years, of materials now in general use would appear to justify. Nevertheless, it is confidently expected that, as improvements are made, as their price falls and as experience is gained in works processing, silicone materials will find an increasing field of application where high temperatures are unavoidable; where overload conditions are frequent; where the volume or weight of apparatus has to be kept to a minimum; and for use at temperatures such as those normally permitted for class "B" insulation, where the conditions of service are so

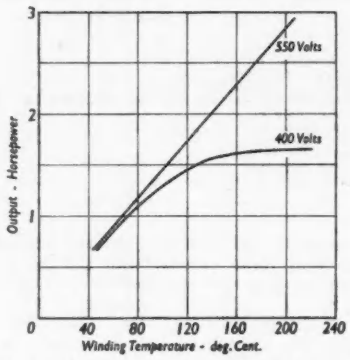


Fig. 1—Output/Temperature Characteristics of Motor B

severe that even the slow deterioration occurring in class "B" materials at these temperatures cannot be tolerated. In addition, there are special fields of application, as typified by the use of silicone fluids in dashpots and of silicone elastomers for cable coverings where the fire risk is high.

There appear to be limitations to the use of resinous silicones, at least in totally enclosed commutator motors, where the rate of wear of brushes is claimed to be considerably accelerated.[7] However, it is beyond the scope of the paper to deal in detail with the fields of application, and much information has already been published on motors for industrial,[6] marine,[8–10] and traction[11] use, on both air-cooled[12] and fluid-filled transformers,[13] and on magnet coils.[14]

Conclusions

Silicone resins possess a moisture resistance at least equal to, and in many ways better than, that of conventional organic resins and varnishes. The property, common to insulation incorporating them, of rapidly drying out from the wet

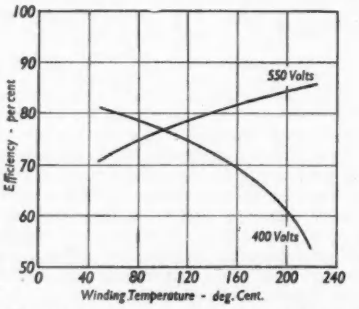


Fig. 2—Efficiency/Temperature Characteristics of Motor B

condition and regaining high values of insulation resistance, is regarded as being of particular importance.

The contention that silicone materials possess at least a 50 deg. Cent. advantage over the analogous class "B" materials is clearly justified by the tests reported in the paper. This, however, does not make either the classification of these materials or the fixing of permissible temperature limits a straightforward task.

The description of class "H" materials set out in the introduction is a modification of the existing classification, which was drawn up before the present widespread use of such materials as woven glass fabric and many of the synthetic resins and oil-modified synthetic resin varnishes. Consequently, it is open to many objections. For example, silicone-varnished glass-fibre insulation and silicone-bonded glass-backed mica are specified as being capable of working at the same temperature, irrespective of the function either serves.

It would be unfortunate if, because of an arbitrary classification, the temperature had to be limited to such a value that the capabilities of some materials were never utilised. It is therefore suggested that the class be split into two parts: one in which all the main insulation consists of built-up mica products with a silicone resin or similar bond, and where the primary purpose of other materials is that of spacing circuit elements at a relatively small potential difference; the other in which materials such as silicone-varnished glass fabric or asbestos, and silicone elastomers, are called upon to act as dielectric barriers. While the temperature limit of 180 deg. Cent. would seem reasonable for the latter, it is suggested that the former could be permitted to work at a hottest-spot temperature of 200 deg. Cent.

A logical extension would be a similar splitting of class "B," those systems of insulation in which the main insulation consists of built-up mica employing, for structural purposes, such materials as glass fabric, asbestos and possibly Terylene, being permitted to work at temperatures 20 deg. Cent. higher than the existing class "B" hottest-spot limit of 130 deg. Cent.

For the different fields of application the decisions would then have to be taken separately as to which parts of any system constituted the main insulation, forming the dielectric barrier, and which constituted the secondary, acting chiefly as a spacer. This would seem to be logical and desirable if the fullest possible use is to be made of available materials.

Appendix

(1) *Approximate Relationship Between the Rate of Deterioration of Insulation and Temperature.*—Over a considerable range about the normal operating temperature the useful life of any insulant, or the time T taken for a particular mechanical characteristic to change a given amount, is an exponential function of temperature θ, namely:

$$T = Ae^{-m\theta}$$

The value of A varies both with the material and with the particular criterion of life chosen. However, m is approximately constant for each class of insulation, and this is generally stated by quoting the increase in temperature $\Delta\theta$ necessary to halve the life of the insulation. These two quantities are related by the expression

$$\Delta\theta = \frac{1}{m}\log_e 2.$$

Moses quotes[11] the increase necessary as being 8 deg. Cent. for class "A" materials, 10 deg. Cent. for class "B" materials, and 12 deg. Cent. for class "H" materials.

(2) *Details of Insulation of Test Motors.*—Three motors, designated A, B and C, have been insulated, using silicone bonds and impregnants throughout, as described below.

Slot liners: Two pieces of glass-backed mica, each 5 mils thick in motor A and 10 mils thick in B and C, were used with the mica faces contiguous. Impregnating varnish DC.993 was used as the bond in motors A and C and DC.996 in motor B.

Conductors: Round copper wires were insulated with a double covering of glass fibres varnished with the same varnishes as used in the slot liners. The sizes of wires and diametrical thicknesses of covering were 24 S.W.G. and 9 mils in motor A, 22½ S.W.G. and 6·5 mils in motor B, and 22½ S.W.G. and 6 mils in motor C.

Overhang taping: For motor A, 3 mil by ½in woven glass tape was heat cleaned and varnished in D.C.996 varnish. For motors B and C a com-

mercial 4 mil by ¼in silicone-varnished woven glass tape was employed.

Slot wedges : These were machined from silicone-bonded asbestos boards.

Terminal boards : These were machined from silicone-bonded glass-fabric boards.

Bearings : Two-spot ball bearings were used in standard end shields. The silicone grease employing a metallic soap thickener was used exclusively for motors B and C.

Stator cores : Standard laminations were coated on one side with dextrin containing china clay. The construction of the cores was standard.

Rotors : Standard cast aluminium ones were used.

Impregnation : Following pre-drying, all motors were impregnated by the double-dip method and cured at the recommended temperatures DC.996 varnish was used on motors A and B and DC.993 varnish on motor C.

(3) *Disposition of Thermo-couples in Stators.*—Only one thermo-couple was used in motor A. This was placed in the middle of a slot, immediately under the slot wedge.

In motors B and C six thermo-couples were used, five being embedded in the windings : one in each overhang, one at each end of a slot, and one in the middle of a slot. The sixth was inserted in a hole drilled in a stator tooth.

(4) *Characteristics of Test Motor B.*—The variations in output and efficiency with winding temperature are shown in Figs. 1 and 2 respectively, as measured by the thermo-couple in the slot, opposite the driving end. Curves are shown at supply voltages of 400V and 550V. It is apparent that, by suitable choice of voltage or by change in design, the output can be nearly doubled by increasing the permissible winding temperature from 100 deg. to 180 deg. Cent. However, it is equally obvious that simply rewinding a motor with class "H" materials does not necessarily permit the output to be materially increased.

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Technical Reports

Tests on Road Bridges. National Building Studies Research Paper No. 16. D.S.I.R. H.M. Stationery Office. Price 3s.—Hundreds of road bridges in this country are more than a century old and were not designed to carry the very heavy traffic which they now have to bear. In 1933 the owners of such bridges were allowed to limit the weight of vehicles using them, but it was found that the bridges could carry, without ill-effects, vehicles much heavier than the limits imposed. In 1936 the Building Research Station started an investigation, on behalf of the Ministry of Transport, to discover the source of the unsuspected strength of the bridges and to find ways of estimating their carrying capacity which would be more accurate than those previously used. The work was discontinued on the outbreak of war, but in 1942 it became essential to know the capacity of the bridges to carry various types of heavy military vehicles and the testing was resumed.

It is difficult to assess the carrying capacity of cast iron girder bridges and masonry arch bridges because the parapet walls, spandrel walls, intermediate jack arches and filling all tend to strengthen the bridge. A series of loading tests was carried out on selected bridges of both kinds. A great deal of useful information was obtained by testing three arch bridges to destruction under static loads. In the testing of other bridges military vehicles of various weights were used as test loads. The strains and deflections measured during the tests were used as a basis for the assessment of the capacity of similar bridges. As a result of the tests a formula for estimating the strength of cast iron girder bridges was produced and this method is now being used by the Ministry of Transport and the Railway Executive.

A number of factors influence the carrying capacity of a brick or masonry arch bridge. These bridges also vary greatly in their individual structural features and it is rare to find two that are identical. It was found impossible to give a single formula for estimating their strength, which is usually much greater than is shown by existing methods of calculation. The report suggests a way of reaching a figure by measuring the spread and deflection of the arch under a known load and estimating the total capacity of the bridge from these measurements.

Timber and Fire Protection. The Timber Development Association, 21, College Hill, London, E.C.4.—The fire resistance of timber is discussed in this booklet, and compared with the fire resistance of other materials. The mechanism of combustion of wood is explained and various "fireproofing" treatments are described. It is pointed out that the idea that timber is highly inflammable is fallacious, and various illustrations are given to support this point of view. The comparative resistances of various kinds of timber to fire are tabulated and a number of fire resistance tests are described.

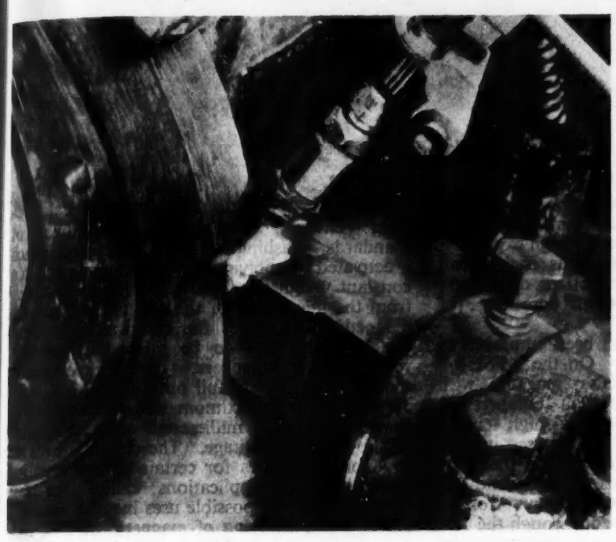
American Engineering News

(By Our American Correspondent)

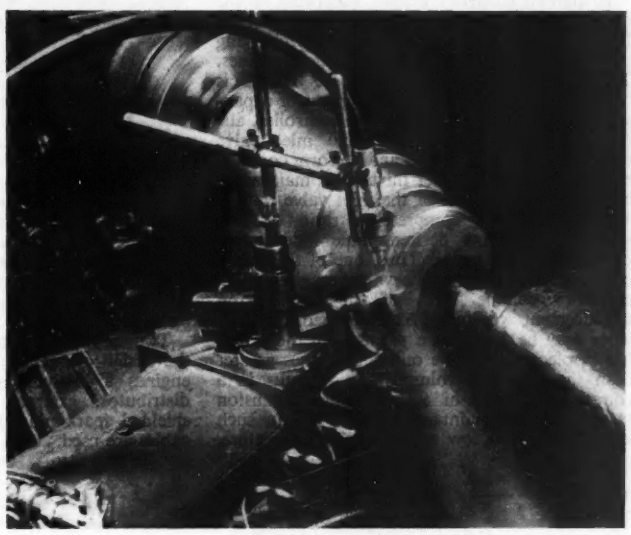
Carbon Dioxide as a Machine Tool Coolant

At a recent National Metal Exposition in Philadelphia, the use of carbon dioxide as a machine tool coolant was demonstrated for the first time by the Pure Carbonic Company, of New York. A jet of liquid CO_2 discharged through a small nozzle so as to impinge a stream of CO_2 "snow" and cold gas upon the work and the tool at the point of contact has been found an excellent coolant. The second illustration shows carbon dioxide being applied to a centre lathe turning. Although the initial cost of CO_2 is greater than that of oil, the ultimate savings due to increased production, longer tool life, better finish, &c., may result in a substantial reduction in overall cost. In general, it is believed that CO_2 as a coolant is likely to find good use where the removal of heat is essential, particularly where fluid coolants do not provide economical tool life at desirable cutting speeds. Again, CO_2 is of definite advantage when machining metal where the recovery of chips without oil or water contamination or heat discoloration is important. The cooling capacity, inert atmosphere, inherent cleanliness, and comparatively simple application of the gas are all important factors in favour of its use. It has been found that the extremely low temperature of the CO_2 jet will cool effectively without any thermal shock. The work and the tool usually remain near normal room temperature, getting neither too hot nor too cold and showing no cracks from heat or cold.

The jets now being used have an orifice in the size range of 0·010in to 0·030in in diameter. The optimum rate of flow tends to be within a range of 15 lb to 30 lb CO_2 per hour per tool. Any air contamination due to the CO_2 gas discharged is not noticeable when comparatively few machines in a relatively open shop are using it. However, adequate ventilation must be provided for large-scale applications, as concentrations of the order of 5 per cent CO_2 in air will be objectionable. CO_2 as a coolant has already been used with good results for practically every machining operation, including grinding, turning, milling, broaching, drilling, and tapping, chiefly of difficult-to-machine metals associated with military projects. A particularly interesting application is the use of CO_2 as a coolant in the grinding of cemented carbide tools. Properly applied, CO_2 makes possible the complete grinding of the carbide tool in one application without the necessity for cooling-off periods, saving much of the normal dry grinding time. Another advantage which has been reported is the longer wheel life obtainable because fewer wheel dressings are required. The photograph reproduced in the first illustration above shows a



Carbon Dioxide Coolant Applied to Tool Grinding



Carbon Dioxide Coolant Applied to Turning

jet of CO_2 being sprayed on a carbide tool which is being sharpened.

A Gas Engine of High Thermal Efficiency

The Nordberg Manufacturing Company, of Milwaukee, Wisconsin, has commenced the production of a series of four-cycle, spark-fired gas engines having thermal efficiencies in the region of 40 per cent. The engines are known as Types "FSE-9" and "FSE-13," and are built with 9in and 13in bore sizes, respectively, in a range of 265 h.p. to 4260 h.p. They are able to burn natural gas, butane, propane, manufactured gas and sewage gas economically. A cross-sectional view of the 13in bore design is reproduced herewith (Fig. 1). The engines have been designed along the lines of the company's four-cycle diesel engines and are convertible to 100 per cent fuel oil or dual fuel operation. The thermal efficiency ranges, according to the firm, from 41 per cent for engines employing the firm's "Supairthermal" system of supercharging to 38 per cent for non-supercharged engines. This high efficiency in such a gas engine is believed to be due to the employment of expansion ratios of up to 12½ : 1 and controlled air-fuel ratios obtained by variable inlet valve timing. To ensure smooth and uniform combustion, the correct air-fuel mixture is maintained by the precise control of the inlet valve timing. Furthermore, the compression ratio can be selected to be any desired value independent of the expansion ratio. Thus, one of the supercharged versions of the new gas engine has a clearance volume 1/11½ of the total piston displacement volume. At full load its inlet valve may be closed at a point when the piston has displaced a volume only eight times greater than the clearance volume. This results in a compression ratio of 9, while the expansion ratio of 12½ is maintained. As a result, such an engine has a low compression temperature, whereby it can operate with minimum excess air without detonating and, at the same time, has a high thermal efficiency due to the high expansion ratio. It has been found that gas engines can be operated without pre-ignition or detonation with a mixture having a small percentage of excess air.

Two ignition systems have been employed in the design of these engines. On the "FSE-9" engines a low-voltage impulse magneto with distributor, external coils, high compression shielded spark plugs and low and high tension cables are used. One spark plug is used in each cylinder, and the magnetos generate and distribute low voltage current through the low tension cables to individual coils adjacent to each plug. High voltage current from the coils is then conducted to each spark plug at the proper firing interval of the respective cylinder. An impulse coupling on the magneto provides a hot spark at engine cranking speed and retards the spark automatically to facilitate easy starting. The ignition system used on the "FSE-13" engines consists of an impulse generator, a selenium rectifier, a transformer-coil and spark plug resistors. Two spark plugs are used in each cylinder and are mounted in water-cooled holders. The generator produces an ignition impulse which is accurately timed with the firing point of each cylinder. The principles employed in this generator eliminate the use of the conventional cam and break point arrangement usually found in such ignition systems.

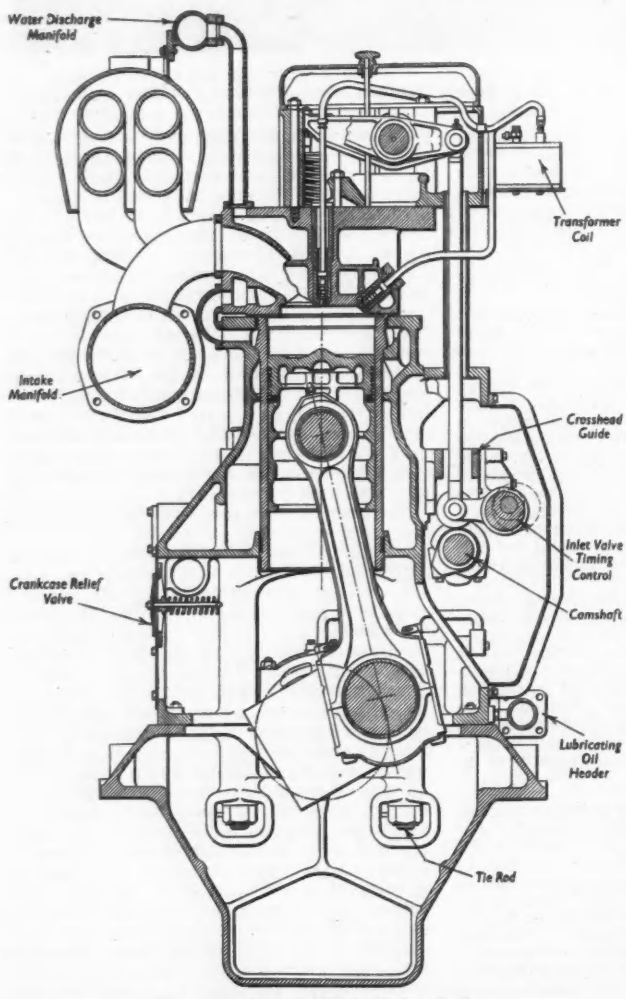


Fig. 1—Nordberg "FSE-13" Gas Engine

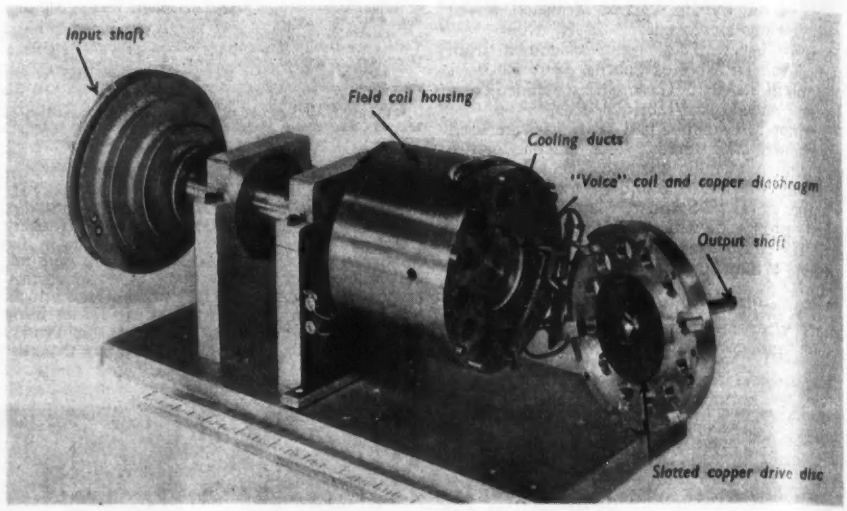


Fig. 2—Fast-acting Electromagnetic Clutch

A Fast-Acting Electromagnetic Clutch

An interesting fast-acting clutch operating on the same moving-coil principle as the electrodynamic loud speaker of an ordinary wireless receiver has been developed by J. Rabinow, head of the Electromechanical Ordnance Division of the National Bureau of Standards, Washington, D.C. The new clutch is activated by applying d.c. to a coil situated in a constant magnetic field. The force resulting from the interaction of the coil current and the magnetic field moves the coil and causes the clutch output disc to be pressed against the rotating input members. In an experimental model of the clutch, full output-shaft torque of 10 ounce-inches maximum was attained in less than a third of a millisecond after application of the actuating voltage. The clutch is believed to offer advantages for certain instrumentation and computor applications calling for fast response, and the possible uses include the rapid starting and stopping of magnetic wire or tape recording media in high-speed electronic computors and high-speed switching uses in telephone dial systems. The "loudspeaker" clutch has been found capable of faster response than electrical or magnetic friction clutches of conventional design. In such conventional clutches time as well as energy is required to build up a field after the actuating voltage is applied.

In the "loudspeaker" clutch, on the other hand, the necessary magnetic field is already in existence before the clutch is actuated. The inductance of the moving coil in the "loudspeaker" clutch is normally small and can be made negligible by means of "bucking" of compensating coils; thus the time required for the coil current to build up so as to press the clutching surfaces together can be made equally negligible. In the N.B.S. experimental model, which is illustrated above (Fig. 2), the magnets and coils rotate with the clutch input shaft. Although a permanent magnet could be used, an electromagnet was chosen; the clutch can thus be easily cleaned of any accumulated magnetic particles when the magnetising current is shut off. Two pairs of slip rings transmit the magnetising and actuating currents to the rotating assembly. A thin, flexible diaphragm is fastened to the actuating coil. When the voltage is applied, the coil jumps forward and presses the clutch output disc between the rotating diaphragm and a backing disc which is also rotating. Vent holes in the output disc, diaphragm and case facilitate cooling and help to avoid compression or rarefaction of air by the diaphragm. Compensating coils are attached to the pole faces of the electromagnet, mounted close to the actuating coils. All the coils are connected in series so that the current is the same in all windings, but the direction of current flow in the compensating coils is opposite to that in the actuating coils. This arrangement cancels out the inductance of the actuating coil to the extent that the coupling between the coils approaches unity and thus minimises the time required for current to rise in the coil after the actuating voltage is applied. In the model tested the compensating coils reduced the inductance, at a 1kc/s frequency, of the actuating

coils to 0·15 millihenry from an uncompensated value of 2·4 millihenries.

Tests were made to determine the clutch response speed and the maximum torque, as well as the effectiveness of the compensating coils. For the response-time tests, an ordinary crystal gramophone pick-up served as the sensing element, its needle resting in a small depression in the clutch output shaft. An oscilloscope was connected to the actuating switch and to the crystal pick-up so that the lapse of time from the closing of the switch to the beginning of output-shaft motion could be observed. With 300V applied both to the electromagnet field coil and to the actuating coil, the output shaft began to move in 200 microseconds and reached full speed in 300 microseconds. With 100V on the field and 215V on the actuating coil, the corresponding delays were 500 and 625 microseconds. The actuating voltages required for fastest response are needed only momentarily; to avoid overheating and coil burn-out they must be reduced promptly after the clutch has reached full speed. The maximum safe values of current for continuous operation were determined to be 0·2A for the electromagnet field coil and 0·5A for the actuating coil. At these currents the maximum output torque was found to be 10 ounce-inches. The effectiveness of the compensating coils was tested by measuring response times with the coil connections reversed, so that the compensating coils aided the actuating coils instead of opposing them. Under the conditions of the test this increased the delay time from 600 microseconds to 900 microseconds. It is expected that the principle of the "loudspeaker" clutch may find application in specialised equipment where light loads must be accelerated at an extremely rapid rate. Although the actuating mechanism rotates in the initial experimental clutch model, an alternative design has been developed in which the actuating means are stationary and operate the clutching means through thrust bearings.

A Universal Contour Forming Machine

We have received particulars of a contour forming machine which is suitable for cold working bar, strip, sheet, tubes, extrusions, &c., in many different metals, and is made in the United States by the Cyril Bath Company. It is designed to form circular, elliptical or rectangular shapes and many combinations of curves, and is made in several sizes to cover a variety of industrial requirements. One of the machines, which are handled in this country by Gaston E. Marbaix, Ltd., Devonshire House, Vicarage Crescent, London, S.W.11, is illustrated on this page.

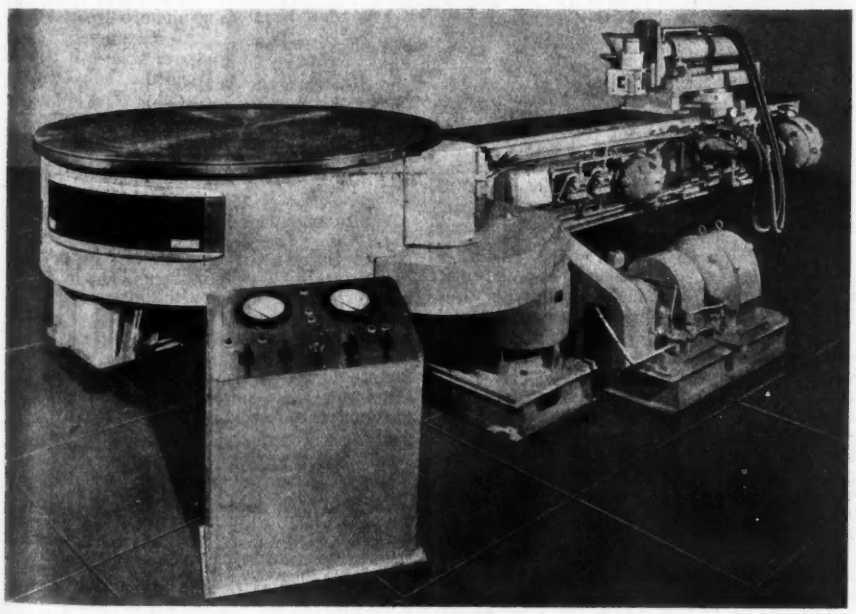
The design is such that a machine can be quickly adapted for stretch forming, or compression forming or for radial draw forming. In stretch forming the die or form or the required contour is bolted to the table and one end of the material is attached to the table by a suitable clamping device. The opposite end of the material is set between the jaws of a hydraulically operated ram head mounted on a carriage on a slide bed projecting from the side of the machine. Through this ram a predetermined load can be applied on the material to first stretch it beyond its elastic limit. Then as the table is rotated tension is maintained by the ram head moving forwards as the material wraps round the die.

When the machine is used for compression forming the action of the ram head is reversed and instead of clamping jaws it is fitted with rolls or shoes designed to press the material into the die contour as the table rotates. This method is used to form similar parts as in stretch forming, but it is effective with components of considerably greater cross-sectional area.

In radial draw forming the machine is set up as for stretch forming, but there is also used a side head with hydraulically operated pressure rolls which force the material as it is formed into the die contours. This method is used where there is severe draw in the radial direction, or when making certain circular, elliptical or rectangular shapes. In these cases the pressure imparted by the rolls of the side head gives an accurate control similar to that exerted by a hold down in an ordinary press, and this method of working is stated to be particularly suitable when handling difficult high alloy metals on the machine.

The general construction of the universal machine can clearly be seen from our illustration. A rigid welded steel frame supports the table assembly and the slide bed. The turntable is held in position on the bed by internal members designed to prevent it from rising during forming operations. A heavy spindle by which the table is rotated is housed in substantial bronze bearings, and the main drive is transmitted through a four-speed a.c. motor through reduction gearing.

The ram head carrying the hydraulic unit, which applies the tension on the material during forming, can be positioned along the bed by the use of plugs in bushed holes, in accordance with the length of the work being handled. Its clamping jaws are operated by an independent hydraulic system and are mounted on a carriage which is adjustable for height on a vertical slide. The ram assembly is pivoted on its carriage so that it can swivel during stretch forming for its movements to follow the curve of the rotating die. During compression forming the ram cylinder action is reversed to press rolls on to the work on the die, and the assembly is locked rigidly in line with the bed. The clamping jaws are designed in accordance with the class of work or profile of the extrusion being handled. All working movements of the machine are controlled from a separate cabinet which can be positioned to give the operator the best view of the work during forming.



Universal Contour Forming Machine

A Bolt and Nut Reclamation System

We have received from London Transport some notes on an interesting system for reclaiming used bolts, nuts, studs, and washers, which has been introduced at its vehicle works and is said to show a saving of about half the cost of new components. At present more than 65,000 items are being reclaimed each week. In addition to this obvious economy, other advantages of the system include continuity of supply when new components are scarce or subject to long delivery; frequently alternatives are found when a part is obsolete or not immediately available. Another important aspect of the system is that it can be operated by elderly or partially disabled personnel. The method of reclamation

Bolt Sorting Bench

varies slightly with different components; the largest number of operations involved is in the case of bolts, which are sorted, identified, viewed, and have their threads dressed as required before being packaged for storage.

The bolt reclamation section was established primarily to deal with the general stock list bolts and studs used for ordinary fastenings on London Transport road vehicles. These parts have for some years been made from 40-ton steel and have rolled threads and upset heads. Special highly-stressed components made from higher quality steel, as well as those cut from bar stock to individual requirements, which are identifiable by special markings, also pass through this section.

Bolts removed in the course of maintenance work or overhaul are delivered in bulk to Chiswick works, where they are first cleaned in a caustic wash. Sorting is carried out in two stages, first by diameter and then by length, type of head, &c., unserviceable bolts being rejected and special types extracted during the first operation. Sorting is done manually at five special benches, each of which has a battery of small bins arranged in a curve, as shown in the illustration above. The bins are open in front and have doors at the back. Bolts to be sorted gravitate from a hopper at the top down a chute to the centre of the bench, where the operator gauges them to determine diameter and length of shank, and throws them into the appropriate bins. Receptacles for special types of bolts which appear less frequently are grouped separately at the sides of the bench.

Sorted bolts are removed from the back of the bins and taken to a viewer's bench, where they are identified for their part numbers. A sample of each type identified by the section is tagged

and displayed on a sampling board. This procedure is intended mainly for identification purposes, but also assists in the selection of suitable alternatives where parts are out of stock, and it serves to draw attention to components of common dimensions from different manufacturers, where there may be scope for reduction in the range of parts.

From the viewer's bench the bolts go in batches to storage bins, and at the same time the progress and materials department are advised that they are available. The bolt threads are dressed in a separate section, where a battery of standard power-driven screwing machines has been laid down. The dies on the machines are set to the average effective diameter for a particular thread so that a thread at the top of its manufacturing tolerance receives a light cut and one at the lower limit is merely cleaned. At intervals samples from each batch are withdrawn for inspection as to gauge, thus providing a check on both the general accuracy of the batch and wear in the screwing dies. Whilst gauging is intended as a check on the thread dressing process and not on the accuracy of the individual part, the limitation is not serious ; where on reuse a reclaimed bolt is found to have a slack thread it is thrown out.

Special highly stressed bolts, such as those used on big ends, are not reclaimed repeatedly, but given a restricted working life. A popmark is made each time they are withdrawn from service and the reclamation section automatically rejects for scrap any bolt carrying three such marks.

Nuts are treated in a similar manner to the bolts, but only one stage of sorting is necessary, for as their threads suffer little in service, retapping is not called for. We understand that an automatic nut sorter is soon to be brought into service. Washers are sorted in one stage, using bolts as gauges ; plain washers being classified "full" (normal) or "reduced" (thin). The range of sizes of studs in use necessitates only one stage of sorting. In the case of bolts or studs specially cut down and rethreaded, although the threaded portion does not possess the same strength as the original rolled thread, this has not been found detrimental.

Where the demand for a particular part declines, the reclamation section is in a position to suggest a form into which it can be converted for re-use. Upon occasion attention is drawn by the department to a particular item that regularly shows undue wear at one place, with a view to the design being improved. It is stated that the reclamation section will materially assist in the eventual adoption of the unified threads recently agreed between Britain, Canada and the United States. Fastenings with British standard threads withdrawn after the introduction of the unified threads will be cut down and rethreaded to the new standard.

Fuel Conversion Equipment

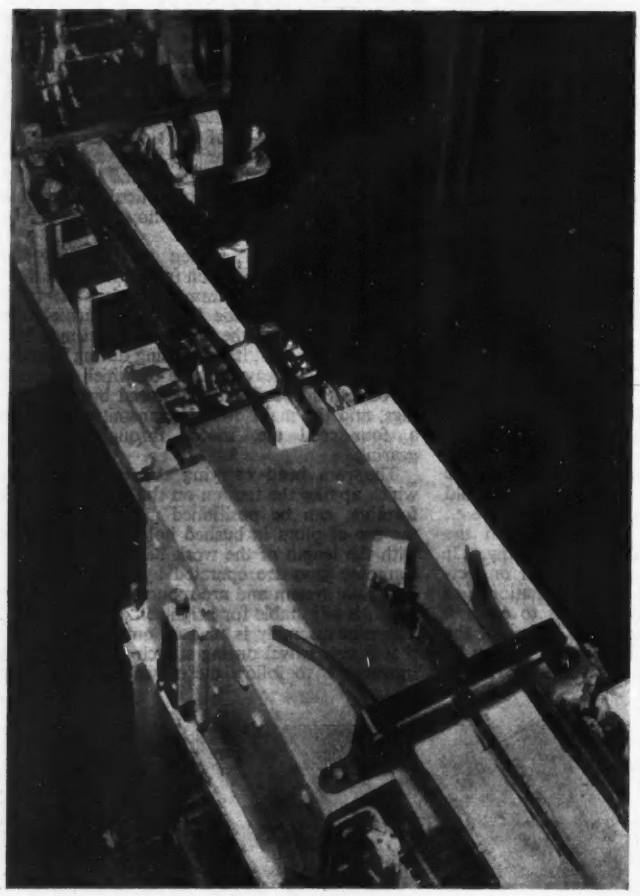
WITH the object of effecting a considerable saving in fuel costs R. A. Lister and Co., Ltd., Dursley, Gloucestershire, has developed a conversion kit to enable the company's Mk. D petrol engine to run on tractor vaporising oil. The conversion equipment consists essentially of a small cast iron vaporiser, an auxiliary petrol container, additional fuel pipes and cocks, with the necessary joints, gasket and control fittings. All the kit can be readily fitted to existing engines without the need of skilled labour and the company has prepared an instruction leaflet which carefully details all the operations required to carry out the conversion, while another leaflet sets forth the procedure for starting, running and stopping.

The additional gasket must be fitted to reduce the compression ratio of 5 to 1 in the petrol engine to 4·5 to 1 for running on tractor vaporising oil, and the auxiliary petrol container holds half a pint of petrol which is required for the starting and stopping of the engine. The amount of petrol is sufficient for about six starts, the engine requiring to run for about five minutes on petrol to allow the vaporiser to be warmed up before changing over to the main fuel. Similarly, the engine should be run on petrol for about half a minute before stopping, so as to ensure easy starting.

As a petrol engine the unit develops 1·5 h.p. at 700 r.p.m. and 2 h.p. at 1000 r.p.m., and when running on tractor vaporising oil the same power may be developed, but the speeds require to be increased to 800 r.p.m. and 1100 r.p.m. respectively. By fitting the conversion kit it is claimed that, due to the price differential between tractor vaporising oil and petrol, the fuel costs will be reduced by two-thirds.

Soap Stream Divider

THE high discharge rate of modern soap cutters has created a demand for a suitable diverting mechanism to adjust the flow to the stamping machines. Such a device, which can be seen in our illustration, has been developed by Henry Simon, Ltd., and is now available to soap manufacturers. It is simple and consists essentially of a special conveyor and a deflector having two receiving faces, while the complete mechanism as designed presents no difficulty with regard to installation. The particular characteristics of soap make it essential that rough mechanical handling is not used ; thus in designing the Simon " Soap Stream Divider " many problems, created by the limiting circumstances of this specialised field, had to be overcome.



Soap Stream Divider

In operation the soap billets emerge in a single stream from the soap cutter and are guided to a conveyor on which they travel towards a centrally pivoted deflector. The moving billet comes into contact with one face of the deflector and is turned into one of two parallel tracks, then the deflector continues to swivel round and presents a second receiving face to the next soap billet, which is turned to the opposite side into the second track. A minimum of pressure is exerted by the deflector and this ensures that effective handling is achieved without damaging or bruising the billet.

The manufacturer states that the new device has been subjected to a number of exacting tests under working conditions at a soap plant and the provision of increased stamping facilities made available by the use of " Soap Stream Divider " made it possible, at this particular plant, to run the soap-cutting machine at a higher rate so that overall production was increased.

African Engineering News

(By Our African Correspondent)

New Copper-Cobalt Mine in Uganda

It is understood that negotiations are nearing completion to provide for an amount of nearly £6,000,000 which, it is estimated, will be required to bring the Kilembe Mines, Ltd., in Uganda, to production. Kilembe's initial production rate will rank the mine among the world's leading cobalt producers and facilities are being provided for expansion.

When production begins, the deposits will be mined from both open pits and underground stopes. At present, preparatory work, including stope development, is being continued while plant designs are being drawn up. A main adit haulage has been established at an elevation of 4500ft and other adits are portalled up to 5000ft in elevation. Ore will be transferred to the mill a mile away by surface railway, but it is anticipated that low level haulage will be established at the mill elevation.

A new, unique metallurgical process has been developed to process the mine's ore. Some of the oxide ore will be concentrated and some will be mixed with the flotation concentrate to make a feed of 650 tons per day for the " Dorrco " fluosolid roasters. The soluble copper and cobalt oxides will then be leached from the roasted material and the electrolytic copper will be deposited from the solution. The high-grade cobalt oxide precipitate will be shipped to Wilmington, Delaware, where it will be refined into cobalt metal. The cost per pound of the copper is expected to be exceptionally low, particularly when credited with the value of the cobalt output. A 208-mile railroad is being built to the mine by the Uganda Government, and the Uganda Electricity Board will build a 240-mile power line to connect the mine with the new Nile River power development. An airport has already been built by the company, which is also continuing construction on a 1500kVA power plant for use during the construction period and as a standby later. Contracts have been let by the government to rebuild roads to the mine.

"THE BEAMA."—Fifty years of industrial electrical manufacturing history are reviewed in a booklet, " The Beama : A Short Account of its Growth and Activities," issued by the British Electrical and Allied Manufacturers' Association, 36 and 38, Kingsway, W.C.2. This publication outlines the development of the Association, its constitution, its activities and the co-operative efforts of its members which have helped to make the electrical industry the second largest exporter of British products.

Industrial and Labour Notes

Committees on Human Factors

Two committees to study human problems in industry have been set up jointly by the Department of Scientific and Industrial Research and the Medical Research Council. One of them is to deal with human factors in individual efficiency and the other with human relations. The division of interest between them is, broadly, that the first committee will study the individual worker and his job, and the second such matters as the relations between the manager and the worker, between the workers themselves, and between the foreman and the technical specialist.

Sir Frederic Bartlett, formerly Professor of Experimental Psychology at Cambridge University, is the chairman of the first committee, whose terms of reference are : " to keep under review the progress of knowledge bearing on the technical efficiency of the individual in industry, and to advise on general policy in research, including applied research and field study." The terms of reference of the other committee are " to examine current activities concerning the study of human relations in industry and to call attention to problems of special timeliness or promise on which research might be undertaken or supported by the D.S.I.R., the Medical Research Council, or other bodies." Mr. A. B. Waring, chairman of Joseph Lucas Industries, Ltd., is the chairman of that committee.

Steel For Shipbuilding

Answering a question in Parliament on Monday last, the Minister of Supply, Mr. Duncan Sandys, said that the quantity of steel delivered to the shipbuilding industry during the past year had been very nearly equal to the total quantity allocated to it. There had been, however, a shortage of steel plate which had often made it difficult for firms to obtain regular deliveries of plate in the sizes and at the dates required. Consultative committees had been set up by the steel and shipbuilding industries to tackle difficulties of that kind, but the problem could only be fully solved by a substantial increase in overall supplies. The Minister went on to say that strenuous efforts had been made to step up the output of steel plate and the rate of production was now 15 per cent higher than in 1950. He was hopeful, he added, that it would be possible very shortly to increase somewhat the supplies of plates to the shipbuilding industry.

The Steel Industry's Development Plans

The annual report of the British Iron and Steel Federation, which has been published this week, says that the end of 1952 marked the virtual completion of the steel industry's first post-war development plan. This plan, it will be recalled, was designed to increase steel capacity to 16,000,000 tons a year and steel production to between 15,000,000 and 15,500,000 tons. Steel production has, in fact, risen from 12,700,000 tons in 1946 to over 16,000,000 tons in 1952, and has thus exceeded the target figure. The whole expansion programme has been based on the construction of additional blast furnace capacity and the steadily increasing use of pig iron. Expenditure on the plan has amounted in all to over £300 million, which was about 18 per cent above the original estimate even after adjustment to allow for subsequent price increases. But, the report adds, the developments carried out have contributed substantially to an increase in labour productivity in steel melting and rolling of 25 per cent between 1946 and 1952.

The report goes on to say that the Federation's advisory committee on development has almost completed its preparation of the industry's second post-war development plan, as a further stage in the continuous process of modernisation and expansion started under the first plan. This second plan is to cover the period from the present time to 1957–58. After consultation with the individual sections of industry, it has been estimated that by 1957–58 the demand for steel will be 21,000,000 ingot tons a year. Under the new plan, therefore, home steel production is to be increased to almost 20,500,000 ingot tons a year, which, together with supplies of reusable steel and, if necessary, a marginal import should enable the requirements to be fully met. No imports of scrap and pig iron are assumed, and the increase in steel production is based entirely on pig iron expansion to an annual output of 15,000,000 tons. Steel capacity will be sufficient, however, to make use of some imported scrap and pig iron if extra output is required. The plan emphasises the importance of early decisions about the further development of coking coal and ore supplies and specifies that the whole of the increase in coke requirements is to be provided by the expansion of coke ovens at iron and steel works. Development under the new plan is to be concentrated mainly at the new sites and plant units established under the first plan. This, it is stated, should enable capacity to be extended at a lower cost per ton of additional output than was possible in the first plan. The total cost of the work envisaged by the second plan is estimated at about £250,000,000 at prices ruling in the early part of last year.

Training in Industrial Relations

Last week-end the British Association for Commercial and Industrial Education, in conjunction with the Institute of Personnel Management, held a conference at Oxford on the subject of " Training for Better Human Relations in Industry." The conference was opened by Mr. Harold Watkinson, Parliamentary Secretary to the Ministry of Labour, who said that the Ministry was consulting with the British Employers' Confederation, the Federation of British Industries, the Trades Union Congress and the various voluntary organisations concerned as to ways in which further progress could be made for the training of supervisors.

In the course of his speech, Mr. Watkinson emphasised that the need for training in better human relations was as important as the need for technical training. He was glad, he said, that attention was being centred not only on the training of a supervisor in his own job, but also on his status and duties within the firm and on his relations with management and with the workers below him. But, Mr. Watkinson added, it was no use sending a foreman to a course and letting him learn about how things should be done if he returned to his firm and was there prevented from making any changes. Mr. Watkinson went on to say that good human relations must be measured by the will to work in the framework of the general behaviour of people in industry, and that the test of good human relations in an organisation was the readiness of that organisation to accept change. He was disturbed, he continued, at the acute anxiety expressed in many industrial centres directly shifts in markets and conditions produced any degree of short-time working or transitional unemployment. Discounting political factors, that was merely a sign that we were not conditioning ourselves to the more difficult days ahead. Full employment in Great Britain in

The Carriage of Strategic Goods to China

Following the Foreign Secretary's recent talks in Washington, the Government has decided to reinforce the embargo on the export of strategic goods to China which was instituted in accordance with the United Nations Resolution of May, 1951, by imposing an additional prohibition on the carriage of such goods to China, from any source, in British ships. The Control of Trade by Sea (China and North Korea) Order, 1953, which has been made by the Minister of Transport, is the first step in giving effect to this decision. It will be followed by the Control of Trade by Sea General Licence.

The Ministry of Transport says that the effect of the Order and the Licence is that on and after March 31st, no British ship registered in the United Kingdom or the Colonies, of 500 gross tons or more, may proceed to sea from anywhere in the world on a voyage to China or North Korea, or between ports in those places, except under the authority of a licence granted by or on behalf of the Minister of Transport. In the case of United Kingdom registered ships, the licence will be in addition to the general trading licence which is already required under the Control of Trade by Sea (No. 2) Order, 1939. Diversions to China without the special licence are prohibited except under duress or stress of weather. Licences will be granted subject to the condition that the ship does not carry, on the voyage to which the licence refers, any item of strategic cargo to China or North Korea. Strategic cargo includes arms and munitions ; electrical and electronic equipment ; machinery and industrial equipment ; metals ; oil, rubber and chemicals ; and transport and marine equipment. As the export of particular items is occasionally authorised, however, there is an exemption for shipments covered by a valid United Kingdom or colonial export licence.

Ships operated from the United Kingdom are to be licensed from London, but for those operated from Hong Kong, Singapore or the Federation of Malaya, licences will be issued locally. Licence application forms may be obtained from the Ministry of Transport, Commercial Services Division, Berkeley Square House (Room 4006), London, W.1.

Bolt and Nut Prices

The Minister of Supply has made the Bolts, Nuts, &c., Prices (Revocation) Order, 1953, which terminates the statutory control of maximum prices for steel bolts, nuts, screws and rivets. The Order came into effect on March 23rd.

The Ministry of Supply says that, now the control is removed, the manufacturers concerned intend, with the agreement of the Minister, to revise their prices. The prices of the majority of the products will be reduced or remain stationary, whilst the prices of some products will be increased. But it is stated that the overall effect will be a net saving to consumers of approximately £250,000 a year. The industry has undertaken to maintain prices at reasonable levels and to make available to the Ministry of Supply, as and when required, information about their costs of production and other matters affecting prices.

Industrial Relations Handbook

A new edition of the " Industrial Relations Handbook," which is compiled by the Ministry of Labour, has been published this week. The first edition of the book was prepared primarily for the use of the Ministry's own staff, but it was issued for general publication in 1944.

The original edition summarised the legislation affecting industrial relations, outlined the development of collective bargaining and described the joint negotiating machinery existing in certain selected industries. It also dealt with workshop collaboration, State provision for the avoidance and settlement of trade disputes, war-time industrial policy and legislation, and the Fair Wages Resolutions of the House of Commons. In addition, there was information about statutory wage regulation, holidays with pay, systems of wage payment, the official cost-of-living index, and the work of the International Labour Organisation. Subsequently four supplements to the book were published, dealing with joint consultation, wage incentive schemes, hours of labour and overtime rates, and the interim index of retail prices. In the new edition all the information contained in the 1944 edition has been brought up to date and certain material hitherto available only in the supplements has been incorporated in the main work. An account is also given of developments since 1944, such as the Industrial Disputes Order, 1951, the Wages Councils Acts, 1945–1948, and the Fair Wages Resolution of October, 1946.

Notes and Memoranda

Rail and Road

ROAD ACCIDENTS.—Casualties on the roads of Great Britain during the first two months of this year were about 1700 more than in the same period of 1952, according to figures issued by the Ministry of Transport. The number of killed and injured in February, according to reports so far received, was 13,104, or 1112 more than in February, 1952. Of this total, 343 were killed and 3373 seriously injured. In January casualties totalled 14,825, the highest figure recorded for this month for fourteen years. The number of persons killed increased to 389, and those seriously injured to 3686.

DIESEL LOCOMOTIVES AND RAILCARS.—A brochure entitled " British Diesel Locomotives and Railcars " has just been published by the Locomotive Manufacturers' Association of Great Britain, 82, Victoria Street, London, S.W.1. This book illustrates and describes briefly typical diesel and diesel-electric locomotives, mines locomotives, and railcars made by member firms of the Association. The publication has been widely distributed throughout the world to railway officials as well as to commercial representatives of Her Majesty's Government, to whom it will serve as a reference work to assist when advising prospective buyers as to the manufacturers in this country most likely to meet their particular requirements.

THE COLLEGE OF AERONAUTICAL AND AUTOMOBILE ENGINEERING.—The laboratories and workshops of the College of Aeronautical and Automobile Engineering, Sidney Street, Kings Road, Chelsea, S.W.3, were recently open to inspection to visitors on the occasion of the distribution of trophies by Lord Brabazon of Tara. The College, which offers primarily a practical training in these branches of engineering, does not receive financial assistance from the Government. Besides its workshops, which are equipped with a representative range of machine tools, there are facilities for mechanical strength testing. The drawing-office at the College is used only for rudimentary instruction in machine drawing. Following a brief address by the Principal, Mr. C. H. Roberts, A.I.Mech.E., Lord Brabazon made some pertinent remarks upon the trends of aeronautical and automobile engineering. In particular he referred to the strength of the challenge which Continental designers and manufacturers had established in the automobile industry, and whilst he certainly did not decry British design, he nevertheless thought that some sections of the industry were not sufficiently aware of its excellence.

Air and Water

FRENCH SHIPBUILDING RESEARCH SOCIETY.—The Institut de Recherches de la Construction Navale, which is the French equivalent of the British Shipbuilding Research Association, was founded in 1948, and is supported by most of the ship and marine engine builders, the manufacturers of marine auxiliary machinery and a number of shipowners. The programme of research includes an investigation into the distribution of stresses in ships' structures and as the result of tests on models of points of stress concentration it is now possible to reduce such concentrations. Trial methods for testing the manœuvrability of ships have been perfected and extensive work has been carried out on the problems of hull vibration. An analysis of the experimental results has led to the formulation of methods for the prediction of natural frequencies from preliminary plans and specifications so that the choice of propelling machinery will be materially assisted. Many ship trial results have been analysed with a view to obtaining closer prediction of ship powers from model tests and as a result of careful study it is possible to adjust torsionmeters to give readings accurate to within 1 per cent.

Miscellanea

INSTITUTE OF FUEL.—H.R.H. The Duke of Edinburgh has graciously signified his willingness to become an Honorary Member of the Institute of Fuel.

COMMERCIAL VEHICLES AND THE ROYAL SHOW.—It has been announced that the Royal Show is amongst the national agricultural shows at which, as a result of a decision by the Society of Motor Manufacturers and Traders, Ltd., no commercial vehicles may be exhibited this year either by manufacturers or distributors.

D.C. SOLENOIDS.—We have received a leaflet describing the d.c. solenoids (series L) made by Westool, Ltd., St. Helen's Auckland, Co. Durham. These solenoids are of cylindrical construction, wound for 6-440V d.c., with a terminal box on the cylindrical surface. They are arranged for universal mounting and give a maximum stroke of 2in, pull or thrust. Characteristic curves of the three solenoids in the series are given in the leaflet.

DISCHARGE OF WATER FROM STEEL PIPES.—Stewarts and Lloyds, Ltd., Brook House, Upper Brook Street, London, W.1, has published a table giving pipe discharges for various sizes of pipes and gradients, based on formulæ recently developed in the firm's research department. The flow from steel tubes, ¼in to 6in in diameter, between gradients of 1 in 100 and 1 in 6000, are given in one table, the second table giving the corresponding figures for standard bitumen-lined welded steel pipes from 6in. to 48in in diameter between the same limits of gradient.

LONDON TELEPHONE SERVICES.—In the course of a visit to the new automatic telephone exchange at New Cross recently the Assistant Postmaster-General, Mr. D. Gammans, said that there had been an increase of 70 per cent in the number of subscribers in the London area as compared with 1939 ; 75 per cent of the exchanges in and around London were now automatic as compared with 60 per cent before the war. Mr. Gammans also stated that the time of waiting for a toll or trunk call in the London area was now less than that required before 1939.

A MULTI-SPEED DRIVE UNIT FOR CLOCKS.—A spring-wound clock motor for use in driving instruments such as chart recorders, which has recently been introduced by British Instrument Company, Ltd., of Weymouth, Dorset, is designed to give different speeds according to requirements by means of quickly and easily fitted interchangeable gear units. The clock consists of a seven-day drive unit, to which is fitted a removable head containing a subsidiary train of gears. Standard gear heads are available for ten different clock speeds and they are held in position by a spring clip on the back of the clock, no special tools being required to fit them.

PHOTOGRAPHY IN THE OIL INDUSTRY.—On Wednesday of last week, Sir Stephen Tallents officially opened an exhibition of photographs by the Shell Photographic Unit at the Kodak Gallery, Regent Street, London. The photographs, which will be on view until April 2nd, show the manifold uses of photography in modern industry and, in particular, how it aids the oil industry. Sections of the exhibition, which gives an overall impression of the flow of oil from well to final product, deal with various aspects of a large oil organisation. The subjects on view show land and air survey work, crude oil production, transportation by ship and pipeline, refineries, distribution, marketing and end uses, and something of the work in the research laboratory.

FOOD MACHINERY.—The Food Manufacturers Federation and the Food Machinery Association have recently discussed the desirability of closer collaboration between food manufacturers and food machinery makers. As a result of the discussions a joint technical committee has been set up, its objects being to secure closer liaison between food machinery manufacturers, food manufacturers and technical organisations. It is stated that the committee intends to disseminate knowledge of British food machinery throughout the food manufacturing industry and, similarly, to keep machinery manufacturers informed of the performance of existing machines and of future requirements. It will also endeavour to encourage a higher standard of mechanisation in the food manufacturing industry.

RESTORATION OF SAND AND GRAVEL WORKINGS.—In a report of the Advisory Committee on Sand and Gravel just published, the Minister of Housing and Local Government recommends the establishment of an after-treatment fund to provide financial assistance towards the restoration of land from which sand and gravel have been excavated. The committee considers that sand and gravel operators should be the principal contributors to the fund, by means of a levy on each cubic yard of sand and gravel produced, and that mineral owners and the Exchequer should also contribute. It is suggested that the levy might be fixed at 1d. per cubic yard for an initial period, and that the Minister should have power to review and vary the rate of contribution at regular intervals.

PNEUMATIC CONTROL EQUIPMENT.—A particularly comprehensive catalogue of its pneumatic control equipment has just been issued by Lang Pneumatic, Ltd., 78A, Birmingham Road, Wolverhampton. This firm makes a wide range of standard air cylinders, control valves and other accessories which can be assembled in a series of combinations to produce pneumatic control systems for all classes of work. By means of drawings and tables the construction and working dimensions of the various components are clearly shown in the catalogue. These components include hand, mechanically, electrically and automatically operated valves ; pilot valves ; reversing valves ; reducing valves ; air cylinders ; air chambers ; air line fittings, &c. The second half of the catalogue is devoted to descriptions of a number of the combinations which can be made in applying the control equipment for plant operation.

UNIVERSITY OF CAMBRIDGE ENGINEERING REPORT.—We have received from the University of Cambridge the report of the acting head of the Department of Engineering. The report includes summaries of the research programme on aeronautics, electricity, heat engines, hydraulics, materials, mechanics, soil mechanics and structures. It is noted in the aeronautical summary that wind tunnel experiments to study the influence of distributed suction on the turbulent boundary layer have continued throughout the year Interesting results are being obtained which may have a bearing on the control of the flow of fluids in the ducts of compressors and turbines. For these experiments the porous surface through which the air is sucked is of filter paper, backed by a flat perforated metal plate with closely spaced holes of 0·02in diameter. This same plate, without its porous covering, is also being used to find whether or not laminar flow can be maintained by suction applied through such a surface which would be more practicable upon an aircraft than the porous surfaces hitherto used for this purpose.

THE BUILDING INDUSTRY AND SCIENCE.—A conference on research held by the National Federation of Building Trades Employers was opened recently by Sir Ben Lockspeiser, secretary of the D.S.I.R. In reviewing the preliminary problems of the industry Sir Ben said that he doubted whether the shape of the building industry was as conducive as it could be to the use of science and scientific methods. The central problem which the industry had to face was its own organisation. Large numbers of small firms would always be needed for small jobs, but, he said, it might be better if more of the smaller firms specialised in particular kinds of sub-contracting work. There were already, of course, many small specialised sub-contractors for plastering, painting, plumbing, tiling, and so on, but did not this need further extension ? And did not the building industry need more men who could influence design in the interest of better production, who specialised in detailed planning and programming of building jobs and on the best methods for carrying out the work ? He asked if such men might not become an invaluable link between the design and erection functions of research in building operations. These, he thought, were the kind of problems which needed to be considered and dealt with before research could be given a proper chance to get to work, and before the building industry could reasonably expect science to operate decisively in its favour.

Personal and Business

MR. E. HEYWOOD SMITH has been appointed a director of The Standard and Pochin Bros., Ltd., Leicester.

MR. C. GODFREY, A.M.I.Mech.E., has been appointed chief engineer of Spiro Gills, Ltd., Pulborough, Sussex.

AIR CONTROL INSTALLATIONS, Ltd., Ruislip, states that Mr. H. D. Roberts, secretary of the company, has been appointed a director.

GENERAL DESCALING, Ltd., has moved from Sheffield to Worksop, Notts (telephone, Worksop 3211 ; telegrams, " Descaling, Worksop ").

ENGINEER REAR-ADMIRAL SIR SYDNEY FREW, K.B.E., has been appointed chief fuel engineer to the Ministry of Fuel and Power, in succession to the late Mr. J. Price Walters.

MR. E. ORLOFF has retired from the London office of the Continental division of Metropolitan-Vickers Electrical Export Company, Ltd. He joined Metropolitan-Vickers (then British Westinghouse) in 1909.

MR. J. A. MATTHEWS, M.I.Mech.E., chief engineer of The Eagle Star Insurance Company, Ltd., has been made a Liveryman of the Worshipful Company of Farriers and a Freeman of the City of London.

THE HYMATIC ENGINEERING COMPANY, Ltd., Redditch, states that Mr. D. G. B. Mountford has been appointed assistant production controller. Mr. Mountford has formerly had charge of the export sales department, in which appointment he is succeeded by Mr. D. H. V. Fereday.

AT the annual meeting of the Liverpool Steam Ship Owners' Association, Mr. C. C. Black, a director of Furness Withy and Co., Ltd., was elected chairman of the association for the coming year, and Mr. H. Leslie Bowes, managing director of the Pacific Steam Navigation Company, was made vice-chairman.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., states that it has acquired, as from April 30th, the cable and wire business of Phillips Electrical Works, Ltd., of Brockville and Montreal, Canada. A new Canadian company is being formed, under the title of Phillips Electrical (1953), Ltd., to continue the business. The chairman of the new company will be Mr. W. H. McFadzean, deputy chairman of British Insulated Callender's Cables, Ltd.

MR. L. J. DAVIES has retired from the post of assistant managing director of Richard Thomas and Baldwins, Ltd. He will continue to serve on the board of the company. His successor as assistant managing director is Mr. G. A. Young, general manager, Ebbw Vale section. Mr. Young has also been appointed a director of The Steel Company of Wales, Ltd. Mr. C. G. Gilbertson has retired from the board of Richard Thomas and Baldwins, Ltd., on account of ill health.

Launches and Trial Trips

CORBURN, motor collier ; built by the Goole Shipbuilding and Repairing Company, Ltd., for William Cory and Son, Ltd.; length 258ft, breadth 39ft 3in, depth 19ft, deadweight 2790 tons, speed 11 knots; British Polar " M 48 M " diesel engine, 1040 b.h.p. at 205 r.p.m. Trial, March 12th.

ROYAL CROWN, oil tanker ; built by Joseph L. Thompson and Sons, Ltd., for Hall Brothers Steamship Company, Ltd.; length between perpendiculars 495ft, breadth moulded 69ft 6in, depth moulded 40ft 4in, deadweight 16,400 tons on 30ft draught, service speed 14 knots ; Doxford oil engine, six cylinders, 670mm diameter by 2320mm stroke, 6800 b.h.p. at 118 r.p.m. Launch, March 16th.

NORDEPIC, motor trawler ; built by the Goole Shipbuilding and Repairing Company, Ltd., for St. Andrews Steam Fishing Company, Ltd.; length 105ft, breadth 23ft 6in, depth 11ft 6in ; Crossley diesel engine, 450 b.h.p. at 310 r.p.m. Launch, March 17th.

KARAMU, motor coaster ; built by Henry Robb, Ltd., for the Union Steam Ship Company of New Zealand ; length between perpendiculars 250ft, breadth moulded 41ft 6in, depth moulded to upper deck 17ft 9in, deadweight 2100 tons on 16ft mean draught, trial speed 11 knots ; three holds, three 114kW diesel-driven generators ; Clark-Sulzer " T P.D.48 " two-stroke diesel engine, five cylinders, 1500 b.h.p. at 225 r.p.m. Trial, March.

BARON KILMARNOCK, oil tanker ; built by the Caledon Shipbuilding and Engineering Company, Ltd., for H. Hogarth and Sons, Ltd.; length between perpendiculars 515ft, breadth moulded 71ft, depth moulded 38ft 9in, load draught 30ft, deadweight 16,500 tons ; Kincaid diesel engine, six cylinders, 6950 b.h.p., trial speed 15 knots ; two 100kW steam-driven generators, one 100kW diesel-driven generator. Launch, March 17th.

British Patent Specifications

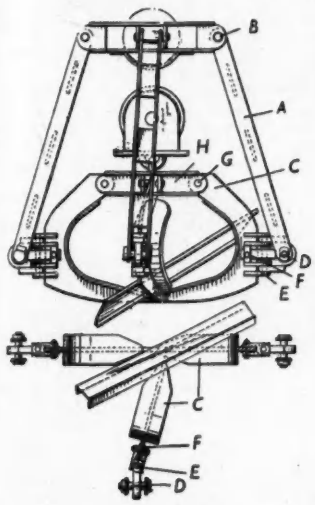
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

CRANES AND LIFTING DEVICES

687,923. January 13, 1949.—GRABS. Heinrich Reichmann, Werdener Strasse, 20, Kettwig, Germany, and Jakob Reichmann, Wilhelmstrasse, 6, Kettwig, Germany, trading as Gebr. Reichmann K. G. Greiferfabrikation.

In this invention, the actuating links of a grab are each connected to the grab arms by two pivoted joints, the axes of which are at right angles one to another so that the arms can swing laterally from each other against spring action. As the drawing shows, there is an upper block to which the actuating links *A* are pivoted at *B*. These links are attached



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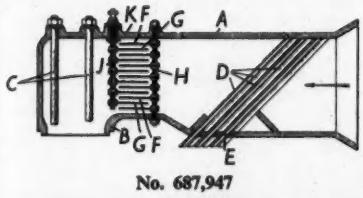
to the grab arms *C* by two joints *D* and *E* at right angles. The return of the pivoted joint *D* to its original position is effected by a double-leafed spring *F*. At the top the grab arms are attached by pivots *G* to a member *H* suspended from the lower block. These joints also permit play. In operation the arms are closed by the wire rope pulling on the lower block and when this cable is slackened the arms open owing to the block falling under its own weight. When, as shown in the lower view, the arms grip a bulky piece of material, they can automatically adjust themselves to it. Distortion of the actuating links *A* cannot occur owing to the arrangement of the joints *E*, which connect the grab arms to the actuating links.—*February* 25, 1953.

DUST SEPARATORS

687,947. March 1, 1950.—AIR FILTER UNIT, Raymond Henri Pierre Devaux, 1, Quai Voltaire, Paris, France.

The invention relates to an air filter unit for internal combustion engines suitable for use with an apparatus for ozonising and ionising the air supply to the engine. The unit is housed in a tubular casing *A*, connected to the carburettor through a



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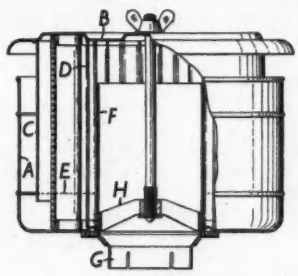
manifold *B* by means of tie-rods *C*. The filter is arranged across the induction portion of the casing and comprises a suitable number of parallel rows of elongated channel-shaped members *D* which are staggered with their channels facing the air flow and are secured at their upper extremities to the inner surfaces of the casing upper wall. The lower ends of the members are vented to atmosphere at *E*, and they slope down in the direction of air flow. The operation of the filter is such that air jets flowing through the unit are forced around the elongated channel members *D*, and whenever the direction of air flow is changed by the members, dust and other impurities suspended in the air are left in the channels. The deposited dust and impurities are discharged outside the unit at *E* under the effect of gravity aided by the air, which passes along the grooves in the channel. Various designs of filter members are shown. The ozonising and ionising unit is arranged in the casing beyond the filter, and comprises a number of horizontal plates *F* and *G* spaced apart to insure, on the one hand, the formation of electrical discharges whereby ozone is produced, and, on the other hand, the ionisation of the air particles, without restricting the air flow to an excessive degree. The plates *F* in one series are secured to a rod *H* mounted on the casing *A*. The plates *F* are also brought to earth potential. The plates *G* in the other series are secured to a rod *J* insulated from earth by a bushing *K* inserted through the wall of the casing. The rod is provided at one extremity with a terminal connected with a corresponding terminal of the electrical supply.—*February* 25, 1953.

687,933. September 28, 1949.—AIR CLEANERS, Cecil Gordon Vokes, Henley Park, Guildford, Surrey.

The invention relates to air cleaners of the oil bath type, in which the filter scrubber is wetted both by capillary action from the bath and by its scrubbing action on the air undergoing filtration. The cleaner comprises a lower casing *A* and an overhanging top cover *B* with a depending cylindrical wall *C*. When the star-shaped cylindrical filter scrubber *D* is clamped between the bottom of the casing and cover, air



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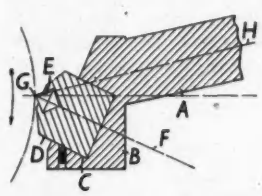
entering beneath the top cover and over the rim of the lower casing and passing down, meets the oil surface indicated at *E* and turns upwards inside the depending wall *C*. It then passes through the filter scrubber *D* and over the rim of a central cylinder *F* extended upwards sufficiently far to form an effective inner wall to the oil bath in the central region. The outlet path may be down through this central cylinder *F* and out from the outlet *G* at the bottom of the casing, or upwards and out from the top of the cover. A spider *H* in the central cylinder carries a securing screw and the cover can be secured on the screw by a wing nut, as shown. The filter scrubber may take the form of a star-shaped element formed of pleated layers of wire gauze with or without intervening textile or other filtering material. A modified cone-shaped form is also shown in the specification.—*February* 25, 1953.

WORKSHOP TOOLS AND APPLIANCES

687,859. March 28, 1950.—DIAMOND TOOLS FOR TRUEING GRINDING WHEELS, Reginald Allen, 26, Warwick Row, Coventry, Warwickshire.

The invention provides a tool in which the diamond is supported securely against the wheel surface when the tool is inclined backwards relative to the direction of movement and in which the axis of the diamond is



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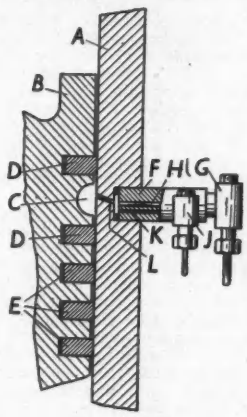
at an angle with respect to the longitudinal axis of the tool. In the drawing there is shown a sectional elevation of the tool. It comprises a shank *A* having formed at one end a housing *B* provided with a recess *C* to receive a stud *D* in which is secured a diamond *E*. The axis *F* of the diamond passing through the cutting point *G* is thus inclined to the axis *H* of the shank. In operation, the tool holder is so set with relation to the grinding wheel that the axis *H* of the shank is inclined backwards relative to the direction of rotation of the wheel. In this way the angular relation of the diamond is contra to the drag angle at which the holder is set, the cutting point being presented to the surface of the wheel in a direction opposed to that of rotation of the wheel, thus ensuring a better cutting action and avoiding the possibility of abrasive particles being crushed into the surface of the wheel.—*February* 25, 1953.

INTERNAL COMBUSTION ENGINES

687,979. November 9, 1950.—LUBRICATION OF PISTONS AND CYLINDERS OF DIESEL ENGINES, David Krijgsman, 139B, Willem Buytewechstraat, Rotterdam, Holland.

The object of the invention is to avoid waste of lubricant and to improve the working condition of the engine as a result of less wear of walls, liners and piston rings, while at the same time the exhaust ports are less subjected to fouling. In the drawing a part of a cylinder *A* is shown in which a piston *B*



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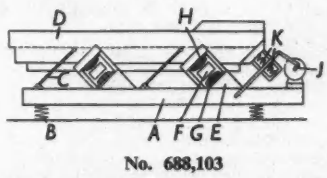
is mounted having a large oil groove *C*. On each side of the oil groove there is provided a piston ring *D* which is rounded off to distribute the oil evenly over the cylinder wall. The other piston rings below the oil groove are shown at *E*. A lubricating oil stud *F* is fitted with a copper packing ring in the cylinder wall. The packing ring is of sufficient thickness and has such an inner diameter as to form a small chamber for accumulating the oil, until it is blown in by air pressure at the timed moment. The air is admitted via a non-return valve *G* and an air passage *H*. The oil is supplied from a special apparatus through a non-return valve *J* and an oil duct *K* and is forced by the air through the passage *L* into the oil groove *C* in the piston. During the operation of a diesel engine every point of the walls of the cylinders and pistons does not have the same temperature. The coolest spot is situated at the greatest distance from the head of the piston. As shown, the lubricant is admitted between the piston rings *D* before the upward stroke of the piston. Consequently the lubricant cannot come into contact with the hot gases in the cylinder before it has lubricated the walls of the piston and the cylinder. The specification also shows the design of the air distributor.—*February* 25, 1953.

SIEVING MACHINES

688,103. September 17, 1951.—SIFTING DEVICES, Fried. Krupp Stahlbau Rheinhausen, Rheinhausen, Niederrhein, Germany.

As shown in the drawing, the sifter comprises a supporting frame *A* carried by springs *B* on a stationary base. Supported by the frame, by means of normally inclined pivoted rods *C*, is a sifter box *D*. At each side of the supporting frame *A* are arranged two supporting members *E* with openings which extend in the direction of oscillation of the sifter box, substantially perpendicular to the rods *C*.



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Rigidly connected to the sifter box *D* at each side are two transverse projections *F* which extend into the openings of the supporting members *E*. On opposite sides of each transverse projection *F* are spaced rubber buffers *G* and *H*, mounted on the supporting members *E*. A crank drive *J* actuates a rocking arm by means of a connecting rod. This arm is located between coupling springs *K*, which bring about the opposed oscillations of the two masses *A* and *D*. The space between each rubber buffer and the adjacent side of the transverse projection can be adjusted so as to vary the stroke of the sifter box.—*February* 25, 1953.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 24, Victoria Street, London, S.W.1.

1 PER CENT CHROMIUM STEEL CASTINGS (ABRASION RESISTING)

No. 1956 : 1953. Price 2s. This is one of a series of standards for steel castings for general engineering purposes and covers the three grades A and B, carbon-chromium, and C, carbon-chromium-molybdenum.

Chemical composition and hardness are specified for all grades of castings and tensile properties are specified for one grade of carbon-chromium castings.

METAL CONTAINERS

No. 1133, Section 10 : 1953. Price 10s. During the last few weeks considerable progress has been made towards the completion of B.S. 1133, "Packaging Code." Two large sections have recently been issued and the B.S.I. has now published the revision of Section 10, "Metal Containers." This means that thirteen of the projected twenty sections are now available and two further sections are likely to be issued shortly.

The new publication has five sub-sections. The first gives details of the materials and the construction of tins and cans and describes basic types and closures; it also discusses decoration, testing and filling and closing procedure. The second sub-section describes materials and construction of metal drums and gives details. The sub-section on metal crates, hampers and trays, describes five broad groups of containers. For collapsible tubes there is information on materials, sizes, weights, decoration, packaging for transport and filling. The sub-section on composite containers also discusses materials, types and sizes. The whole of the section is amply illustrated and there are definitions of many trade terms.

Codes of Practice

THE Council for Codes of Practice, Construction and Engineering Services, has now published eighty-six codes in final form. The total price of these codes is £16 18s. 6d., but the publisher, the British Standards Institution, 24, Victoria Street, London, S.W.1, states that it will supply on demand the complete set of eighty-six documents at a price of £12 for the set. This reduced price is subject to revision as further final codes are published.

SMALL SEWAGE TREATMENT WORKS

Code 302.100. The Council for Codes of Practice for Buildings has now issued as a draft for comment Code 302.100, "Small Sewage Treatment Works." This code describes suitable methods of treatment for the sewage from groups of houses, institutions, &c., with populations of about 350 and under, where connections to a public sewer are impossible. It does not deal with the treatment of trade wastes, nor with the disposal of surface or subsoil water. The various types of installation are set out, together with full descriptions of septic tanks, settling tanks and biological filters. The disposal of both the tank effluent and filter effluent by humus tanks, surface irrigation or sub-surface irrigation is fully described. The importance of maintenance is stressed, and the main items requiring attention are set down. A series of six drawings illustrating various types of septic tank, settling tank and biological filter is appended to the code. The code is in draft form and is subject to amendment in the light of comments received which should be submitted by April 21, 1953. Copies may be obtained from the British Standards Institution, 24–28, Victoria Street, London, S.W.1, price 5s.

CENTRAL HEATING BY LOW-PRESSURE HOT WATER

Code 341.300. The Council for Codes of Practice for Buildings has now issued as a draft for comment Code 341.300, "Central Heating by Low-Pressure Hot Water," prepared for the Council by a joint committee convened by the Institution of Mechanical Engineers and the Institution of Heating and Ventilating Engineers. The code gives guidance, at all stages, on the setting up, and the maintaining in good order, of installations to provide central heating by low-pressure hot water (i.e. where the system is open to the atmosphere at one or more points). In drafting the code, the committee has assumed (*a*) that the design of such an installation will be entrusted to a fully qualified engineer, who will assure himself that "balance" is maintained in the system, and (*b*) that the work will be carried out under qualified supervision. The code is in draft form and is subject to amendment in the light of comments received, which should be submitted by April 15, 1953. Copies may be obtained from the British Standards Institution, 24–28, Victoria Street, London, S.W.1, price 15s.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ELECTRIC RAILWAY SOCIETY

Sat., April 11th.—Fred Tallant Hall, 153, Drummond Street, London, N.W.1, Film Show, 3 p.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., March 30th.—LEEDS CENTRE : Lighting Service Bureau, 24, Aire Street, Leeds, 1, Annual General Meeting, followed by "Lighting and Vision as Age Advances," H. C. Weston, 6.15 p.m.

Tues., March 31st.—CARDIFF CENTRE : S. Wales Electricity Board, Cardiff, "Development of Lamps Other than Tungsten," E. J. G. Beeson, 5.45 p.m.

Wed., April 1st.—EDINBURGH CENTRE : Lighting and Cleansing Department, 357, High Street, Edinburgh, Annual General Meeting, 7 p.m.——NEWCASTLE CENTRE : Minor Durrant Hall, Oxford Street, Newcastle upon Tyne, 1, Annual General Meeting, 6.15 p.m.——SWANSEA GROUP : Minor Hall, Y.M.C.A., Swansea, "Electrical and Radiation Characteristics of Discharge Lamps for Industrial Lighting," E. J. G. Beeson, 6 p.m.

Thurs., April 9th.—MANCHESTER CENTRE : N.W. Electricity Board, Town Hall Extension, Manchester, "Glass—An Old Material in a New Light," P. M. Davidson, 6 p.m.——NOTTINGHAM CENTRE : E. Midlands Electricity Board, Smithy Row, Nottingham, Presidential Address, W. J. Wellwood

Fri., April 10th.—HUDDERSFIELD GROUP : Electricity Showroom, Market Street, Huddersfield, Annual General Meeting, 7.15 p.m.

INCORPORATED PLANT ENGINEERS

Thurs., April 2nd.—PETERBOROUGH BRANCH : Eastern Gas Board's Demonstration Theatre, Church Street, Peterborough, "Industrial Fire Protection," W. H. Tuckey, 7.30 p.m.

Mon., April 6th.—DUNDEE BRANCH : Mathers Hotel, Dundee, "Water Engineering with Special Reference to Equipment," Gilbert Little, 7.30 p.m.

Tues., April 7th.—EDINBURGH BRANCH : Heriot Watt College, Edinburgh, "Elementary Industrial Electronics," J. H. Jones, 7 p.m.

Wed., April 8th.—E. MIDLANDS BRANCH : Welbeck Hotel, Nottingham, "Peak Steam Demands and Thermal Storage," E. G. Ritchie, 7 p.m.

Thurs., April 9th.—NEWCASTLE UPON TYNE BRANCH : Roadway House, Oxford Street, Newcastle upon Tyne, "Oil Injection Method of Separating and Uniting Joints on Shaft Couplings," C. S. Clarke, 7.30 p.m.

INSTITUTE OF ECONOMIC ENGINEERING

To-day, March 27th.—Engineers' Club, Albert Square, Manchester, "Methods Time Measurement," B. Davis, 7 p.m.

Sat., April 4th.—Christian Institute, 70, Bothwell Street, Glasgow, "Paper-work as Time Study Sees It," E. Ronalds, 10.30 a.m.

INSTITUTE OF INDUSTRIAL SUPERVISORS

Thurs., April 9th.—LONDON CENTRAL SECTION : The Polytechnic, Regent Street, London, W.1, "Relationships Between Management and Trade Unions," For Management J. G. McLeod, For the Trade Unions A. M. F. Palmer, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

To-day, March 27th.—Conway Street Secondary School, Birkenhead, "Photo-Elasticity," J. Ward, 7 p.m.

Thurs., April 9th.—JUNIOR SECTION DISCUSSION : 85, Minories, London, E.C.3, "So You Want to Build a Ship," 7 p.m.

INSTITUTE OF PETROLEUM

Wed., April 8th.—26, Portland Place, London, W.1, "The Present Status of the Art of Cracking," W. C. Dickerman, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Wed., April 8th.—E. MIDLANDS CENTRE : Mechanics Institute, Nottingham, "Rear Axles," R. H. Wilson, 7.30 p.m.

Thurs., April 9th.—WESTERN CENTRE : Grand Hotel, Bristol, Annual General Meeting, Film Show, 7.30 p.m.

INSTITUTE OF WELDING

To-day, March 27th.—E. OF SCOTLAND BRANCH : 25, Charlotte Square, Edinburgh, "Application of Jigs and Fixtures for Steel Fabrication," 7.30 p.m.

Wed., April 1st.—MANCHESTER BRANCH : Reynolds Hall, College of Technology, Manchester, Annual General Meeting, "Welding as Applied to Locomotive Construction and Maintenance," G. Foster, 7.15 p.m.

Thurs., April 9th.—S. LONDON BRANCH : Caxton Hall, Westminster, London, S.W.1, Annual General Meeting, Debate, "That This Meeting Regrets That Standardised Inspection Tests are Not Statutorily Compulsory on all Welded Work," 6.30 p.m.——LEEDS BRANCH : Lighting Service Bureau, Aire Street, Leeds, Annual General Meeting.——N.E. (TYNESIDE) BRANCH : Mining Institute, Neville Hall, Newcastle upon Tyne, "Welding of Deck-Houses," W. Muckle, 7 p.m.

Fri., April 10th.—BIRMINGHAM BRANCH : James Watt Memorial Institute, York House, Great Charles Street, Birmingham, 3, Annual General Meeting, Technical Films, 7 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Tues., March 31st.—CHEMICAL ENGINEERING GROUP: Geological Society, Burlington House, Piccadilly, London, W.1, "The Production of Acetic Anhydride from Acetone," W. G. Daroux, 5.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

To-day, March 27th.—YORKSHIRE ASSOCIATION : Royal Victoria Station Hotel, Sheffield, "The Lee-McCall System of Prestressed Concrete," M. S. Wright, "Some Applications of Soil Mechanics," J. Holt, 7 p.m.

Tues., March 31st.—ROAD MEETING : Great George Street, Westminster, London, S.W.1, "Factors Affecting the Riding Qualities of Machine-Laid Concrete Roads," R. H. H. Kirkham, 5.30 p.m.

Thurs., April 9th.—N.W. ASSOCIATION : Engineers' Club, Albert Square, Manchester, "General Developments in Sewage Works' Design," D. Johnson, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, March 27th.—EDUCATION DISCUSSION CIRCLE : Savoy Place, London, W.C.2, Discussion on "Special Features of Courses in Electrical Engineering in the Royal Navy," opened by L. S. Bennett, 6 p.m.

Mon., March 30th.—INFORMAL MEETING : Savoy Place, London, W.C.2, Discussion on "Use and Abuse of Research," opened by S. Whitehead, 5.30 p.m.——S. MIDLAND CENTRE : James Watt Memorial Institute, Great Charles Street, Birmingham, Discussion on "Electric Heating," opened by E. H. Cox, 6 p.m.

Tues., March 31st.—N. MIDLAND CENTRE : Chemistry Lecture Theatre, The University, Leeds, "275kV Developments on the British Grid System," D. P. Sayers, J. S. Forrest and F. J. Lane, 6.30 p.m.

Wed., April 8th.—N. SCOTLAND SUB-CENTRE : Caledonian Hotel, Aberdeen, Centre Chairman's Address, T. S. A. Primrose, Annual General Meeting, 7.30 p.m.

Thurs., April 9th.—ORDINARY MEETING : Savoy Place, London, W.C.2, "Special Effects for Television Studio Productions," A. M. Spooner and T. Worswick, 5.30 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Tues., March 31st.—S.W. BRANCH : Grand Hotel, Broad Street, Bristol, "Photoelastic Methods of Stress Analysis," H. D. Haddon, 7.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., April 7th.—39, Elmbank Crescent, Glasgow, Annual General Meeting, "The Fatigue Strength of Marine Shafting, Part II—Large-Scale Investigation of the Effect of Fillet Radius on the Torsional Fatigue Strength of Marine Shafting," T. W. Bunyan and H. H. Attia, 7.15 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, March 27th.—Storey's Gate, St. James's Park, London, S.W.1, Annual General Meeting, Annual Report, including Statement of Accounts, 5.30 p.m.

Sat., March 28th.—YORKSHIRE BRANCH, GRADUATES' SECTION : College of Technology, Pond Street, Sheffield, "The Use of Oil Injection Fitting in Steelworks Maintenance," J. A. Abrahams, 2.30 p.m.

Wed., April 1st.—WESTERN BRANCH, GRADUATES' SECTION : St. Mary's College, Cheltenham, "The Weight Aspects of Aero-engine Design," D. W. Hersee, 7 p.m.

Thurs., April 9th.—E. MIDLANDS BRANCH : Loughborough College, Discussion on "Education and Training in Engineering Management," opened by H. G. Nelson, 7.30 p.m.

Fri., April 10th.—GENERAL MEETING ARRANGED IN CONJUNCTION WITH THE EDUCATION GROUP : Storey's Gate, St. James's Park, London, S.W.1, "The Athlone Fellowship Scheme for the Practical Training in Industry of Canadian Engineering Graduates in Great Britain," W. Abbott, 5.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Tues., March 31st.—ORDINARY MEETING : Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Alternatives to the Conventional P.C.L.C. Telecommunications Cable," J. Gerrard, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Tues., March 31st.—DUNDEE SECTION : Works Visit to North of Scotland Hydro-Electric Board, Power Station, Carolina Port, Dundee.——LUTON SECTION : Small Assembly Room, Town Hall, Luton, "Some Visits to American Factories Engaged in Jobbing Engineering," G. P. E. Howard, 7.15 p.m.

Wed., April 1st.—NOTTINGHAM SECTION : Victoria Station Hotel, Milton Street, Nottingham, "Lighting for Production," F. Jamieson, 7 p.m.

Thurs., April 2nd.—READING SECTION : Great Western Hotel, Reading, "Fatigue of Metals," J. A. Pope, 7.15 p.m.——YORKSHIRE GRADUATE SECTION : Works Visit to Hepworth and Grandage, Ltd., St. John's Works, Bradford, 6.45 p.m.

Tues., April 7th.—LUTON GRADUATE SECTION : Peahen Hotel, London Road, St. Albans, "Standardisation and the Utilisation of Materials," E. L. Diamond, 7.30 p.m.

Thurs., April 9th.—LEICESTER SECTION : Windsor Room, Bell Hotel, Leicester, "Gear Finishing," H. Pearson, 7 p.m.——LONDON SECTION : Royal Empire Society, Northumberland Avenue, London, W.C.2, "Building a Steam Turbine," A. C. Annis, 7 p.m.——ROCHESTER AND DISTRICT SUB-SECTION : Rotary Room, Sun Hotel, Chatham, "Improvements and Their Hindrances," C. R. Whitaker, 7.30 p.m.

Fri., April 10th.—W. WALES SECTION : Central Library, Alexandra Road, Swansea, "Advanced Science and the Production Engineer," Llewellyn Jones, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., March 31st.—NORTHERN IRELAND BRANCH : College of Technology, Belfast, Annual General Meeting, 6.45 p.m.

Fri., April 10th.—WESTERN COUNTIES BRANCH : Geology Lecture Theatre, The University, Bristol, Annual General Meeting, 6 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Mon., April 6th.—N.E. SECTION : Neville Hall, Mining Institute, Neville Street, Newcastle upon Tyne, Annual General Meeting, 7 p.m.

Wed., April 8th.—SOUTHAMPTON SECTION : Polygon Hotel, Southampton, Annual General Meeting and Film Evening, 7.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, March 27th.—INFORMAL MEETING : Townsend House, Greycoat Place, London, S.W.1, "Copying Lathes," K. J. Downes, 7 p.m.

Wed., April 1st.—MIDLAND SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, Discussion Evening, "Press-working Machines, Methods and Problems," 7 p.m.

Fri., April 10th.—ORDINARY MEETING : Townsend House, Greycoat Place, London, S.W.1, "Developments in the Design of the Steam Locomotive," D. M. Hunter, 7 p.m.

LIVERPOOL METALLURGICAL SOCIETY

Thurs., April 9th.—Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "The Basic Processes Involved in the Tempering of Plain Carbon and Low Alloy Steels," W. S. Owen, Annual General Meeting, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, March 27th.—Engineers' Club, Albert Square, Manchester, Annual General Meeting, "Friction Between Solid Bodies," R. Schnurman, 6.45 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Mon., March 30th.—Mining Institute, Neville Hall, Newcastle upon Tyne, "The Preservation of Oil Tanker Hulls," John Lamb and E. V. Mathias, 6.15 p.m.

ROYAL AERONAUTICAL SOCIETY

To-day, March 27th.—Chemistry Lecture Theatre, University College, Gower Street, London, W.C.1, Full-Day Discussion on "Fatigue."

Tues., March 31st.—4, Hamilton Place, London, W.1, "Experimental Work on Boundary Layer Flow," W. E. Gray, 7 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Tues., March 31st.—Manson House, Portland Place, London, W.1, "The Presentation of Control Theory and the Training of Control Engineers," G. L. d'Ombrain, 6.30 p.m.

STOKE-ON-TRENT ASSOCIATION OF ENGINEERS

Wed., April 8th.—Midlands Electricity Board, Back Glebe Street, Stoke, "Gears and Their Applications," H. J. Watson, 7 p.m.